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LECTURE NOTES
FOR
CHEMICAL STUDENTS.

BY
EDWARD FRANKLAND, D.C.L., F.R.S.,

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LECTURE NOTES

FOR

CHEMICAL STUDENTS.

CHAPTER I.

INTRODUCTORY.

DEFINITION.—Chemistry is the science which treats of the composition of all kinds of matter, and of those changes in composition which result from the action, either of different kinds of matter upon each other, or of external forces upon one and the same kind of matter.

SIMPLE AND COMPOUND MATTER.—All kinds of matter are divided into two great classes—*simple substances*, and *compound substances*. A simple substance is one out of which it is impossible to obtain, by any known process, two or more essentially different kinds of matter. A compound substance, on the other hand, is one which can be resolved into two or more simple substances. The simple substances at present known are sixty-two in number, and are termed *elements*. By the combination of these elements with each other, all the infinitely varied forms of terrestrial matter are produced.

MODES OF CHEMICAL ACTION.—Matter undergoes chemical change in five different ways, viz.:—

1st. By the direct combination of elements or compounds with each other.

2nd. By the displacement of one element or group of elements in a body by another element or group of elements.

3rd. By a mutual exchange of elements or groups of elements in two or more bodies.

4th. By the rearrangement of the elements or groups of elements already contained in a body.

5th. By the resolution of a compound into its elements, or into two or more less complex compounds.

ATOMIC WEIGHT.—Chemists assign to every element a number called its *atomic weight*. This number is not fixed according to any invariable rule, but the following, especially the second, are the chief considerations which serve as guides in its determination :—

1st. The smallest proportion by weight in which the element enters into or is expelled from a chemical compound,—the smallest weight of hydrogen so entering or leaving a chemical compound being taken as unity.

2nd. The weight of the element in the solid condition which, at any given temperature, contains the same amount of heat as seven parts by weight of solid lithium at the same temperature.

3rd. The weight of the element which, in the form of gas or vapour, occupies, under like conditions of temperature and pressure, the same volume as one part by weight of hydrogen.

The atomic weight of a compound is the sum of the atomic weights of its elements.

The atomic weights of the elements are given in the Table at page 6.

ATOMS AND MOLECULES.—The proportional amount of any element represented by its atomic weight, as above described, is commonly called an *atom* of that element.

When an element is isolated, or separated from every other kind of matter, its atoms still exist, except in a few cases, in combination with each other. In many instances the atoms of isolated elements are associated in pairs when thus combined. Such an isolated atom or group of atoms constitutes an *elementary molecule*.

The bulk of a molecule, or the *molecular volume* of an element in the gaseous or vaporous condition, is the same as the molecular volume of hydrogen at the same temperature and pressure; and the *molecular weight* of an element is in a large number of cases twice its own atomic weight.

The following is a list of those elements whose molecular volumes have been determined.

Molecules containing of the element

<i>One atom. Monatomic Molecules.</i>	<i>Two atoms. Diatomic Molecules.</i>	<i>Three atoms. Triatomic Molecules.</i>	<i>Four atoms. Tetrameric Molecules.</i>	<i>Six atoms. Hexatomic Molecules.</i>
Mercury. Cadmium. Zinc.	Hydrogen. Oxygen. Chlorine. Bromine. Iodine. Fluorine. Nitrogen. Sulphur. Selenium.	Oxygen (as Ozone).	Phosphorus. Arsenic.	Sulphur.

It will be perceived from the above Table that an element may have two distinct molecular weights. This is known to be the case with oxygen and sulphur.

The molecular weight of a compound is, with very few exceptions, identical with its atomic weight. The molecular volume or the space occupied by the combining proportion of a compound is, with very few exceptions, equal to that occupied by two combining proportions, or one molecule, of hydrogen. Hence the law—*equal volumes of all gases and vapours contain, at the same temperature and pressure, an equal number of molecules.*

With very few exceptions, therefore, the molecules of all compounds in the gaseous or vaporous condition, no matter how great may be the aggregate volume of their constituents, occupy, when compared at the same temperature and pressure, one uniform volume, which is exactly the same as that filled by one molecule of hydrogen. Thus

vol.	vol.	vol.
1 of Hydrogen + 1 of Chlorine	form 2 of Hydrochloric acid.	
1 of Hydrogen + 1 of Bromine vapour 2 of Hydrobromic acid.	
2 of Hydrogen + 1 of Sulphur vapour 2 of Sulphuretted Hydrogen.	
2 of Hydrogen + 1 of Oxygen 2 of Steam.	
3 of Hydrogen + 1 of Nitrogen 2 of Ammonia.	
4 of Hydrogen + x of Carbon vapour 2 of Marsh-gas.	
6 of Hydrogen + 1 of Oxygen + 2x of Carbon vapour 2 of Alcohol vapour.	
12 of Hydrogen + 1 of Oxygen + 5x of Carbon vapour 2 of Amylic alcohol vapour.	

CHEMICAL AFFINITY.—The force or power which holds together the elements of a compound is termed *chemical affinity*.

Elements which readily combine with each other, and develop much heat on combination, are said to have a powerful affinity for each other. The elements which thus exhibit towards each other a great affinity are possessed of widely different properties; and when their compounds are decomposed by an electric current, the constituents are evolved at the opposite poles. Those elements which, under such circumstances, make their appearance at the *positive* pole are termed *electro-negative* or *negative* elements, whilst those disengaged at the negative pole are called *electro-positive* or *positive* elements. It must be remembered, however, that the difference between these two classes is one of degree only; they insensibly merge into each other, since the members of both classes exhibit a graduated intensity of the positive or negative quality. Thus potassium is more positive than sodium, and oxygen more negative than sulphur, whilst mercury is negative to sodium but positive to chlorine.

The following eight elements are negative towards the remaining fifty-four elements, which are more or less positive:—

Fluorine.	Oxygen.
Chlorine.	Sulphur.
Bromine.	Selenium.
Iodine.	Tellurium.

Although two positive or two negative elements can combine together chemically, yet their union is rarely attended with such striking phenomena as are manifested when the combination takes place between a positive and a negative element.

CHAPTER II.

CHEMICAL NOMENCLATURE.

THE study of every science necessitates an acquaintance with the system of names and peculiar modes of expression which have been found most convenient to denote the materials and to describe the phenomena which form its objects. Such names and modes of expression form the groundwork of the language of every science, upon the right employment of which depend the precision and accuracy of scientific definition.

The nomenclature of a science ought to be distinguished for its clearness and simplicity; but it is by no means easy to secure these conditions in a science like chemistry, where the rapid progress of discovery necessitates the continual addition of new and the frequent alteration of old names. The chemical name of a substance should not only identify and individualize that substance, but it should also express the composition and constitution of the body, if a compound, to which it is applied. The first of these conditions is readily attained; but the second is much more difficult to secure, inasmuch as our ideas of the constitution of chemical compounds—of the mode in which they are built up as it were—require frequent modification. On this account all attempts to frame a perfectly consistent system of chemical nomenclature have hitherto been only partially successful.

It has been already mentioned that the number of elements at present known is sixty-two. These have received the names given in the following Table, in which the twenty-two most important elements are distinguished by the largest type, those next in importance by medium type, whilst the names of elements which are either of rare occurrence, or of which our knowledge is yet very imperfect, are printed in the smallest type.

Name.	Sym- bol.	Atomic weight.	Name.	Sym- bol.	Atomic weight.
ALUMINIUM	Al	27.5	Molybdenum...	Mo	92
ANTIMONY	Sb	122	NICKEL	Ni	58.8
ARSENIC	As	75	Niobium.....	Nb	97.6
BARIUM	Ba	137	NITROGEN	N	14
BISMUTH	Bi	208	Osmium	Os	199
BORON	B	11	OXYGEN	O	16
BROMINE	Br	80	PALLADIUM	Pd	106.5
Cadmium	Cd	112	PHOSPHORUS	P	31
Cæsium	Cs	133	PLATINUM	Pt	197.4
CALCIUM	Ca	40	POTASSIUM	K	39
CARBON	C	12	RHODIUM	Rh	104
Cerium	Ce	92	Rubidium	Rb	85.5
CHLORINE	Cl	35.5	Ruthenium.....	Ru	101
CHROMIUM.....	Cr	52.5	Selenium	Se	79
COBALT	Co	58.8	SILICON	Si	28.5
COPPER	Cu	63.5	SILVER	Ag	108
Didymium	D	96	SODIUM	Na	23
FLUORINE	F	19	STRONTIUM	Sr	87.5
Glucinum	G	14	SULPHUR	S	32
GOLD	Au	196.7	Tantalum	Ta	137.5
HYDROGEN	H	1	Tellurium	Te	128
Indium	In	113.4	Thallium.....	Tl	204
IODINE	I	127	Thorium	Th	231.5
IRIDIUM	Ir	198	TIN	Sn	118
IRON	Fe	56	TITANIUM	Ti	50
Lanthanum	L	92	TUNGSTEN	W	184
LEAD	Pb	207	URANIUM	U	120
Lithium	Li	7	Vanadium	V	51.2
MAGNESIUM	Mg	24	Yttrium	Y	68
MANGANESE	Mn	55	ZINC	Zn	65
MERCURY	Hg	200	Zirconium	Zr	90

These elementary substances have been long divided into two great classes—*metals* and *non-metals*, the latter being also sometimes termed *metalloids*. The metals are by far the more numerous, the non-metals comprising only the following thirteen elements—Boron, Bromine, Carbon, Chlorine, Fluorine, Hydrogen, Iodine, Nitrogen, Oxygen, Phosphorus, Selenium, Silicon, Sulphur.

The names of the elements can scarcely be said to have been given according to any rule; many of them are derived from some prominent property of the bodies themselves, whilst others have a mythological origin. An attempt has been made to distinguish the metals by the termination *um*, as potassium, sodium, &c.; but the common metals, such as gold, copper, and iron, still retain their original names; and one substance, selenium, which at the time of its discovery was regarded as a metal, has had no change made in its name, although further research has divested it of all metallic attributes. An important group of electro-negative non-metals—fluorine, chlorine, bromine, and iodine—have received the termination *ine*; three are distinguished by the terminal syllable *on*, viz. carbon, silicon, and boron; and three others have *gen* for their final syllable, viz. oxygen, hydrogen, and nitrogen, these last names being derived from Greek words denoting the property possessed by these elements of generating respectively acid, water, and nitre.

When two elementary bodies unite together, they form a chemical compound of the first order, to which the name *binary compound* has been applied. The names of these compounds are formed from those of their constituents, the name of the positive constituent or some abbreviation thereof, with the terminal *ic*, preceding that of the negative constituent, which is made to terminate in *ide*, thus:—

Potassium and Sulphur form Potassic sulphide.			
Sodium	„	Oxygen	„ Sodic oxide.
Silver	„	Chlorine	„ Argentic chloride.
Zinc	„	Iodine	„ Zincic iodide.
Calcium	„	Chlorine	„ Calcic chloride.

But the same elements frequently form with each other two compounds, in which case the one which contains the smaller proportion of the negative element is distinguished by changing the terminal syllable of the name of its positive constituent into *ous*, the terminal *ic* being retained for the compound con-

taining the larger proportion of the negative element. Thus,

One atom of tin and two atoms of chlorine form Stannous chloride.

One atom of tin and four atoms of chlorine form Stannic chloride.

Sometimes, however, the same elements form with each other more than two compounds. In these cases the prefixes *hypo* and *per* are employed as marks of distinction; but their use is very rarely required.

If a binary compound contains oxygen, and forms an acid when made to unite with water, or a salt when added to a base, it is termed an *anhydride* or *anhydrous acid*. Thus,

One atom of carbon and two atoms of oxygen form carbonic anhydride.

Two atoms of nitrogen and five atoms of oxygen form nitric anhydride.

Two atoms of nitrogen and three atoms of oxygen form nitrous anhydride.

One atom of sulphur and three atoms of oxygen form sulphuric anhydride.

One atom of sulphur and two atoms of oxygen form sulphurous anhydride.

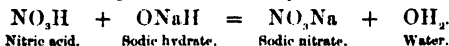
In the following cases, the systematic names have not displaced the trivial and irregular names used for the same substances:—

Systematic Name.	Trivial or irregular name.
Hydric oxide	Water.
Hydric sulphide	Sulphuretted hydrogen.
Hydric selenide	Seleniuretted hydrogen.
Hydric telluride	Telluretted hydrogen.
Hydric chloride	Hydrochloric acid.
Hydric bromide	Hydrobromic acid.
Hydric iodide	Hydriodic acid.
Hydric fluoride	Hydrofluoric acid.
Hydric carbide	{ Marsh-gas or light carburetted hydrogen.
Hydric nitride.....	Ammonia.
Hydric phosphide	Phosphuretted hydrogen.
Hydric arsenide	Arsenuretted hydrogen
Hydric antimonide.....	Antimonuretted hydrogen.

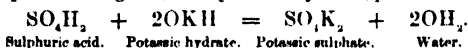
The term *acid* was originally applied only to substances possessing a sour taste like vinegar; but analogy has necessitated the application of the same name to a large number of com-

pounds which have not this property. In the modern acceptation of the name, an acid may be defined as a compound containing one or more atoms of hydrogen, which become displaced by a metal when the latter is presented to the compound in the form of a hydrate. The hydrogen capable of being so displaced may be conveniently termed *displaceable hydrogen*. An acid containing one such atom of hydrogen is said to be *monobasic*, two such atoms *dibasic*, &c. Acids of a greater basicity than unity are frequently termed *polybasic acids*.

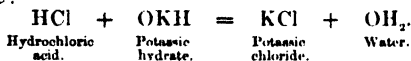
Thus nitric acid gives, with sodic hydrate, sodic nitrate :



Sulphuric acid gives, with potassic hydrate, potassic sulphate :



And hydrochloric acid gives, with potassic hydrate, potassic chloride :



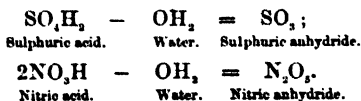
When an acid contains oxygen, its name is generally formed by adding the terminal *ic* either to the name of the element with which the oxygen is united, or to an abbreviation of that name ; thus sulphur forms, with oxygen, sulphuric acid ; nitrogen, nitric acid ; and phosphorus, phosphoric acid. But it frequently happens that the same element forms two acids with oxygen ; and when this occurs, the acid containing the larger amount of oxygen receives the terminal syllable *ic*, whilst that containing less oxygen is made to end in *ous*. Thus we have sulphurous acid, nitrous acid, and phosphorous acid, each containing a smaller proportion of oxygen than that necessary to form respectively sulphuric, nitric, and phosphoric acids.

In some instances, however, the same element forms more than two acids with oxygen, in which case one of the two Greek words *hypo*, under, and *hyper*, over, is prefixed to the name of the acid. Thus an acid of sulphur containing less oxygen than

sulphurous acid is termed hyposulphurous acid; and another acid of the same element containing, in proportion to sulphur, more oxygen than sulphurous acid and less than sulphuric, might be named either hypersulphurous acid, or hyposulphuric acid; but the latter term has been universally adopted. The prefix *per* is frequently substituted for *hyper*; thus in the case of chlorine, which forms the following four acids with oxygen, viz. hypochlorous acid, chlorous acid, chloric acid, and hyperchloric acid, the latter is generally named perchloric acid; but *per* can only be used as a prefix to the acid containing the largest proportion of oxygen.

Some acids do not contain oxygen amongst their constituents, but consist of sulphur or hydrogen united with other elements. This peculiarity of composition is expressed in their nomenclature by the prefixes *sulpho* or *sulph*, and *hydro* or *hydr*: thus sulpharsenic acid and sulphostannic acid denote acids composed respectively of sulphur, hydrogen, and arsenic; and sulphur, hydrogen, and tin; whilst the names hydrochloric acid and hydriodic acid are given to acids composed, the first of hydrogen and chlorine, and the second of hydrogen and iodine. The terminals *ous* and *ic* are also applied to these acids in exactly the same manner as to the oxygen acids: thus we have sulpharsenious and sulpharsenic acid, the latter containing a larger proportion of sulphur than the former; but the application of the first of these terminals has not hitherto been found necessary in the case of hydrogen acids, since no element has yet been observed to form more than one acid with hydrogen.

The term *anhydride* or *anhydrous acid* is applied to the residue obtained by the abstraction (in combination with oxygen as water) of all the displaceable hydrogen from one or two molecules of an oxygen acid. Thus,



The term *base* is applied to three classes of compounds, all of which are converted into salts by the action of acids. These are—

1st. Certain compounds of metals with oxygen, such as sodic oxide (Na_2O), zincic oxide (ZnO), &c.

2nd. Certain compounds of metals with the compound radical hydroxyl (HO), such as sodic hydrate ($\text{Na}(\text{HO})$), zincic hydrate ($\text{Zn}(\text{HO})_2$), &c.

3rd. Certain compounds of nitrogen, phosphorus, arsenic, and antimony, such as ammonia (NH_3).

There are also a few organic compounds to which the name *base* is sometimes given, but which are not included in the above classes; it is, however, unnecessary further to allude to them here.

The bases of the first class are named in accordance with the rules already given for compounds of two elements. The following bases, however, still retain their irregular names:—

Systematic names.	Irregular names.
Baric oxide	Baryta.
Strontic oxide	Strontia.
Calcic oxide	Lime.
Magnesian oxide	Magnesia.
Aluminic oxide	Alumina.
Glucinic oxide	Glucina.
Zirconic oxide	Zirconia.

The names of the bases belonging to the second class are formed by changing the terminal syllable of the name of the metal into *ic* or *ous*, and the word hydroxyl into *hydrate*. Thus cæsium and hydroxyl form cæsic hydrate ($\text{Cs}(\text{HO})$); barium and hydroxyl, baric hydrate ($\text{Ba}(\text{HO})_2$); and iron and hydroxyl, ferric hydrate ($\text{Fe}_2(\text{HO})_6$).

A few of these bases have trivial or irregular names, which are almost invariably used instead of the systematic names:—

Systematic names.	Irregular names.
Potassic hydrate	Potash.
Sodic hydrate	Soda.
Lithic hydrate	Lithia.

The bases of the third class are distinguished by the terminal syllable *ine*, except nitrine, (NH_3), which retains its trivial name ammonia. These bases belong almost exclusively to the department of organic chemistry, and their nomenclature could not be advantageously discussed here.

It has been already mentioned that by the mutual action of an acid and a base upon each other, a *salt* is produced. If the salt be free from oxygen and sulphur, like common salt, (NaCl), it is termed a *haloid salt*; if it contain oxygen, it is termed an *oxysalt*; and if this oxygen be replaced by sulphur, it is distinguished as a *sulphosalt*.

The haloid salts are named according to the rules for binary compounds above given, thus:

Name.	Formula.
Sodic chloride	NaCl .
Calcic iodide	CaI_2 .
Ferrous bromide	FeBr_2 .
Ferric bromide.....	Fe_2Br_6 .

Oxysalts are divided into *normal*, *acid*, and *basic*.

A *normal salt* is one in which the displaceable hydrogen of the acid (see page 9) is all exchanged for an equivalent amount of a metal or of a positive compound radical.

The following examples will serve to illustrate this definition of a normal, or, as it is sometimes incorrectly called, a *neutral salt*, the displaceable atoms of hydrogen in the acid, and the metal by which they have been displaced in the salt, being printed in italics :—

Acid.	Normal salt.
Nitric acid NO_3H	<div style="display: inline-block; vertical-align: middle;"> { Sodic nitrate NO_3Na. Calcic nitrate $(\text{NO}_3)_2\text{Ca}''$. </div>
Sulphuric acid..... SO_4H_2	<div style="display: inline-block; vertical-align: middle;"> { Potassic sulphate Calcic sulphate $\text{SO}_4\text{Ca}''$. </div>
Phosphoric acid PO_4H_3	<div style="display: inline-block; vertical-align: middle;"> { Potassic phosphate Calcic phosphate..... $(\text{PO}_4)_2\text{Ca}''$. </div>
Hypophosphorous acid.. $\text{PO}_2\text{H}_2\text{H}$...	Sodic hypophosphite ... $\text{PO}_2\text{H}_2\text{Na}$.
Phosphorous acid PO_2HH_2 ...	Potassic phosphite PO_2HK .

Acid.		Normal salt.
Metaphosphoric acid ...	PO_3H	Lithic metaphosphate... PO_3Li .
Pyrophosphoric acid ...	$\text{P}_2\text{O}_7\text{H}_4$	Calcic pyrophosphate... $\text{P}_2\text{O}_7\text{Ca}''_2$.
Nordhausen sulphuric acid	$\text{S}_2\text{O}_7\text{H}_2$	Sodic bisulphate
Unknown acid	$\text{Cr}_2\text{O}_7\text{H}_2$...	Potassic bichromate ... $\text{Cr}_2\text{O}_7\text{K}_2$.

An acid salt is one in which the displaceable hydrogen of the acid is only partially exchanged for a metal or positive compound radical.

The following examples illustrate the constitution and nomenclature of these salts:—

Acid.		Acid salt.
Sulphuric acid ...	SO_4H_2	Hydric sodic sulphate SO_4HNa .
Carbonic acid ...	$\text{CO}_3\text{H}_2?$	Hydric potassic carbonate... CO_3HK .
Phosphoric acid...	PO_4H_3	Hydric disodic phosphate... $\text{PO}_4\text{H}_2\text{Na}_2$.
		Dihydric sodic phosphate ... $\text{PO}_4\text{H}_2\text{Na}$.
		Microcosmic salt $\text{PO}_4\text{H}(\text{NH}_4)\text{Na}$.
		(Hydric ammonic sodic

Acid salts are produced almost exclusively from polybasic acids.

When the number of bonds of the metal or compound positive radical contained in a salt exceeds the number of atoms of displaceable hydrogen in the acid, the compound is usually termed a basic salt—as, for instance,*

Acid.		Basic salt.
Carbonic acid	CO_3H_2	{ Malachite $\text{CO}_3\text{H}_2\text{Cu}''_2$.
		{ Blue cupric carbonate $\text{C}_2\text{O}_4\text{H}_2\text{Cu}''_3$.
Sulphuric acid.....	SO_4H_2	{ Tribasic cupric sulphate $\text{SO}_4\text{H}_2\text{Cu}''_3$.
		{ Turpeth mineral $\text{SO}_4\text{Hg}''_2$.

These and most, if not all, other basic salts do not differ essentially in their constitution from the normal and acid salts. This will be seen from the arrangement of their atoms given under the different metals entering into their composition.

The nomenclature of organic bodies is founded upon the same principles as that of inorganic compounds; but its discussion could not be conveniently introduced here.

* For an explanation of this term see Chap. III. p. 18.

CHAPTER III.

CHEMICAL NOTATION.

SYMBOLIC NOTATION.—Every element is represented by a symbol, which is frequently the initial letter of the name of the element; but as in some cases the names of two or more elements begin with the same letter, it is necessary to distinguish them by the use of a second letter in small type, which is either the second letter of the word, or some other letter prominently heard in its pronunciation; thus carbon, cadmium, cobalt, and cerium all begin with the same letter; but they are distinguished by the symbols C, Cd, Co, and Ce. In the use of the single letters, the non-metallic elements have the preference; thus oxygen, hydrogen, nitrogen, sulphur, phosphorus, boron, carbon, iodine, and fluorine are expressed by the single letters O, H, N, S, P, B, C, I, and F; whilst the metals osmium, mercury, nickel, strontium, platinum, bismuth, cobalt, iridium, and iron are symbolized by two letters each; thus Os, Hg (hydrargyrum), Ni, Sr, Pt, Bi, Co, Ir, and Fe (ferrum). In the selection of the single letter for other cases, preference is given to the most important element; thus sulphur, selenium, and silicon are all non-metallic elements, beginning with the same letter; but sulphur being the most important, the single letter S is assigned to it, whilst selenium and silicon are denoted respectively by Se and Si.

The symbols of compounds are formed by the simple juxtaposition of the symbols of their constituent elements. Such a group of two or more symbols is termed a *chemical formula*. Thus:

Argentio chloride..... AgCl.
Zincic oxide ZnO.

The symbols not only represent the elements for which they are used, but they also denote a certain definite proportion by weight of each element; the formula HCl, for instance, does not merely denote a compound of hydrogen and chlorine, but it signifies a molecule of that compound containing one atom

(1 part by weight) of hydrogen, and one atom (35·5 parts by weight) of chlorine. When, therefore, the molecule of a compound contains more than one atom or combining proportion of any element, it is necessary to express such fact in the formula : this is done by the use of a coefficient placed after the symbol of the element :

Zinc chloride	ZnCl_2 .
Ferric chloride	Fe_2Cl_6 .
Stannous chloride	SnCl_2 .
Stannic chloride	SnCl_4 .

When it is necessary to denote two or more molecules of any compound, a large figure is placed before the formula of the compound ; such a figure then affects every symbol in that formula : thus $3\text{SO}_4\text{H}_2$ means three molecules of the compound SO_4H_2 .

The changes which occur during chemical action are expressed by equations, in which the symbols of the elements or compounds, as they exist before the change, are placed on the left, and those which result from the reaction on the right. Thus, taking an example from each of the five kinds of chemical action before mentioned, we have

- (1) $\text{Zn} + \text{Cl}_2 = \text{ZnCl}_2$.
Zinc. Chlorine. Zinc chloride.
- (2) $2\text{HCl} + \text{Zn} = \text{ZnCl}_2 + \text{H}_2$.
Hydrochloric acid. Zinc. Zinc chloride. Hydrogen.
- (3) $\text{SO}_4\text{Cu} + (\text{NO}_3)_2\text{Ba} = \text{SO}_4\text{Ba} + (\text{NO}_3)_2\text{Cu}$.
Cupric sulphate. Baric nitrate. Baric sulphate. Cupric nitrate.
- (4) $(\text{CN})\text{O}(\text{NH}) = \text{N}_2\text{H}_4(\text{CO})$.
Ammonic cyanate. Urea.
- (5) $2\text{OH}_2 = \text{O}_2 + 2\text{H}_2$.
Water. Oxygen. Hydrogen.

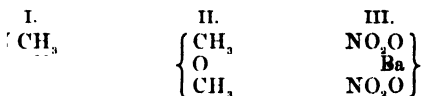
The sign +, as seen from the foregoing examples, is placed between the formulæ of the molecules of the different substances which are brought into contact before the reaction, and of those which result from the change. This sign must never be

used to connect together the constituents of one and the same chemical compound.

The sign — is only very rarely used in chemical notation, but when employed it has the ordinary signification of abstraction; thus,



Use of the bracket.—The bracket has been employed in various senses in chemical formulæ; but in the following pages it is used in notation for one purpose only, viz. for expressing chemical combination between two or more elements which are placed perpendicularly with regard to each other and next to the bracket in a formula. Thus in the following cases,



the formula No. I. signifies that two atoms of carbon are directly united with each other, No. II. that two atoms of carbon are linked together, as it were, by an atom of oxygen, the latter being united to both carbon atoms; whilst in like manner No. III. indicates that one atom of oxygen in the formula of the upper line is linked to another atom of oxygen in the formula of the lower line, by an atom of barium.

Use of thick letters.—As a rule, the formulæ in this book are so written as to denote that the element represented by the first symbol of a formula is directly united with all the active bonds of the other elements or compound radicals following upon the same line: thus the formula SO_4H_2 , (sulphuric acid) signifies that the hexad atom of sulphur is combined with the four bonds of the two atoms of oxygen, and also with the two bonds of the two semi-molecules of hydroxyl. Such a formula is termed a *constitutional formula**.

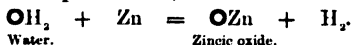
Occasionally, however, owing to the atomic arrangement of

* For further information on this subject see *ATOMICITY OF ELEMENTS AND COMPOUND RADICALS*, pages 17 and 26.

a compound not being known, its formula cannot be written according to this rule; and in order to prevent such *molecular* or *empirical formulae** from being mistaken for constitutional formulae, the first symbol of a constitutional formula will always be printed in thick type. It deserves also to be mentioned that, as a rule, the element having the greatest number of bonds will occupy this prominent position. Thus,

Sulphuric acid.....	SO₂ Ho ₂ .
Water	OH₂ .
Nitric acid	NO₂ Ho.
Microcosmic salt.....	PO HoAmoNa _o .

ATOMICITY OF ELEMENTS.—It has been already stated that the atomic weight of an element is the smallest proportion by weight in which that element enters into or is expelled from a chemical compound. The atoms of the various elements, the relative weights of which are thus expressed, exhibit very different values in chemical reactions. Thus an atom of zinc is equivalent to two atoms of hydrogen; for, when zinc is brought into contact with steam at a high temperature, one atom of zinc expels from the steam two atoms of hydrogen and occupies their place—thus,



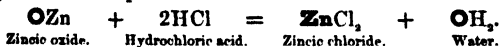
Again, when zincic oxide is brought into contact with hydro-

* A *molecular formula*, sometimes called *rational*, is one in which the atomic composition of a molecule is expressed, but without reference to the manner in which the elements are combined amongst themselves. An *empirical formula* merely expresses, by the smallest integers, the proportional number of atoms of each element entering into the composition of a compound. Thus the three formulae of ferric hydrate are written:—

Empirical formula	FeH ₂ O ₃ .
Molecular „	Fe ₂ H ₄ O ₆ .
Constitutional „	Fe₂ Ho ₄ .

Thus both constitutional and rational formulae are essentially molecular formulae, whilst empirical formulae afford no indication of the number of atoms entering into the composition of a molecule; they are, in fact, only used to represent bodies the molecular weights of which are unknown.

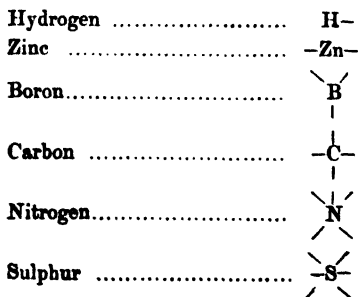
chloric acid, the place of the zinc becomes once more occupied by hydrogen, but two atoms of hydrogen are found to be necessary to take the place of one atom of zinc :



In like manner one atom of boron can be substituted for three atoms of hydrogen, one atom of carbon for four, one of nitrogen for five, and one atom of sulphur for no less than six atoms of hydrogen.

This combining value of the elementary atoms is termed their *atomicity*, *equivalence*, or *atom-fixing power*; and an element with an atom-fixing power equal to that of one atom of hydrogen is termed a *monad*, with twice that power a *dyad*, with thrice a *triad*, with quadruple a *tetrad*, with quintuple a *pentad*, and, with an atom-fixing power equal to six times that of hydrogen, a *hexad*.

To avoid any speculation as to the nature of the tie which enables an element thus to attach to itself one or more atoms of other elements, I have named each unit of atom-fixing power a *bond*,—a term which involves no hypothesis as to the nature of the connexion. A monad element has obviously only one such bond; a dyad, like zinc, two; a triad, like boron, three, and so on. The number of bonds possessed by an elementary atom may be graphically represented by lines in the following manner:—



In symbolic notation, the same idea is conveyed by the use of dashes and Roman numerals placed above and to the right of the symbol of the element ; thus,

Hydrogen.....	H ⁱ ,	Carbon.....	C ^{iv} ,
Zinc	Zn ⁱⁱ ,	Nitrogen	N ^{tr} ,
Boron	B ⁱⁱⁱ ,	Sulphur	S ^{vi} .

Elements with an odd number of bonds are termed *perissads*, whilst those with an even number are named *artiads*.

No element, either alone or in combination, can exist with any of its bonds disconnected ; hence *the molecules of all elements with an odd number of bonds are generally diatomic, and always polyatomic*; that is, they contain two or more atoms of the element united together. Thus,

	Symbolic.	Graphic.
Hydrogen	H ₂	H—H
Chlorine	Cl ₂	Cl—Cl
Nitrogen	N ₂	N≡N
		P=P
Phosphorus.....	P ₄	$ \begin{array}{c} \quad \\ P=P \end{array} $

An element with an even number of bonds can exist as a monatomic molecule, its own bonds satisfying each other. Thus,

	Symbolic.	Graphic.
Mercury	Hg ⁱⁱ	(Hg)
Cadmium	Cd ⁱⁱ	(Cd)
Zinc	Zn ⁱⁱ	(Zn)

It is nevertheless obvious that such an element may also exist as a polyatomic molecule. Oxygen furnishes us with an example of this ; for in its ordinary condition it is a diatomic molecule, and in the allotropic form of ozone, a triatomic molecule :

	Symbolic.	Graphic.
Oxygen	O'' ,	$\text{O}=\text{O}$
Ozone	O'' ,	$\begin{array}{c} \text{O}-\text{O} \\ \diagdown \quad \diagup \\ \text{O} \end{array}$

In order to avoid the unnecessary use of atomicity-marks in symbolic notation, I shall never attach them to a monad, or to oxygen, which, it must be remembered, is always a dyad. Neither will the atomicity-coefficient be attached to the tetrad element carbon, in the formulæ of organic bodies, unless this element plays the part of a dyad—an occurrence of extreme rarity. When not otherwise marked, therefore, carbon must always be understood to be a tetrad.

It will also, as a rule, be unnecessary to mark the atomicity of the elements which are expressed by symbols in thick type, because their atomicity is clearly indicated by the sum of the atomicities of the elements or compound radicals placed to their right, or connected with them perpendicularly by a bracket. Thus in the formula



each atom of carbon is united with three atoms of the monad chlorine, whilst the bracket indicates that the two atoms of carbon are also united by one bond of each, thus denoting **C** to be a tetrad element.

From what has just been said with regard to carbon, it is evident that the atomicity of an element is, apparently at least, not a fixed and invariable quantity: thus nitrogen is sometimes equivalent to five atoms of hydrogen, as in ammoniac chloride, (**N**⁵**H**₅**Cl**), sometimes to three atoms, as in ammonia (**N**³**H**₃), and sometimes to only one atom, as in nitrous oxide (**O****N**₂). But it is found that this variation in atomicity always takes place by the disappearance or development of an even number of bonds: thus nitrogen is either a pentad, a triad, or a monad; phosphorus and arsenic, either pentads or triads; carbon and tin, either tetrads or dyads; and sulphur, selenium, and tellurium, either hexads, tetrads, or dyads.

These remarkable facts can be explained by a very simple and obvious assumption, viz. that *one or more pairs of bonds belonging to the atom of an element can unite and, having saturated each other, become, as it were, latent*. Thus the pentad element nitrogen becomes a triad when one pair of its bonds becomes latent, and a monad when two pairs, by combination with each other, are, in like manner, rendered latent,—conditions which may be graphically represented thus:—

Pentad.



Triad.



Monad.



And in the case of sulphur:—

Hexad.



Tetrad.



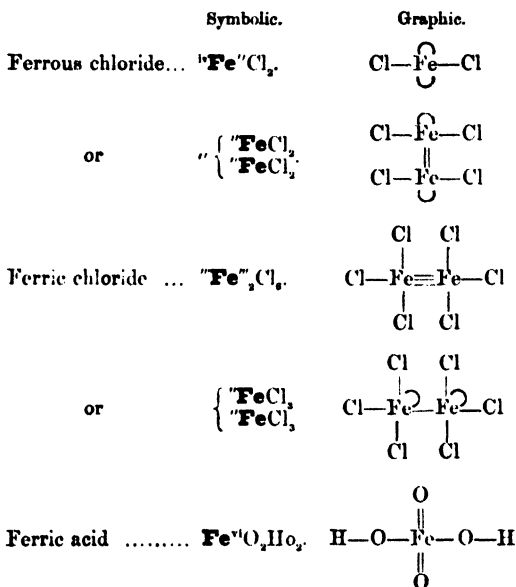
Dyad.



Adopting this hypothesis, it will be convenient to distinguish the maximum number of bonds of an element as its *absolute atomicity*, the number of bonds united together as its *latent atomicity*, and the number of bonds actually engaged in linking it with the other elements of a compound as its *active atomicity*. The sum of the active and latent atomicity of any element must evidently always be equal to the absolute atomicity. Thus in sulphuric acid ($\text{S}^{\text{VI}}\text{O}_2\text{H}_2$) the absolute and active atomicities are both =vi, therefore the latent atomicity =0. In sulphurous acid ($\text{S}^{\text{IV}}\text{O}_2\text{H}_2$) the active atomicity =iv, and consequently the latent =vi – iv = ii; whilst in sulphuretted hydrogen ($\text{S}^{\text{II}}\text{H}_2$) the active and latent atomicities are respectively ii and iv.

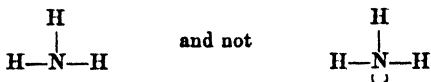
The apparent exceptions to this hypothesis nearly all disappear on investigation: thus iron, which is a dyad in ferrous compounds (as FeCl_2), a tetrad in cubical pyrites (FeS^{IV}), and a hexad in ferric acid (FeO_3H_3), is apparently a triad in ferric chloride (FeCl_3); but the vapour-density of ferric chloride shows that its formula must be doubled—that, in fact, the two

atoms of the hypothetical molecule of iron (Fe_3) have not been completely separated. The formulæ of the ferrous and ferric chlorides and of ferric acid then become



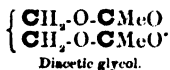
It will be remarked that the number of bonds supposed to be combined with each other in the atom of iron in ferrous chloride is expressed in one of the above formulæ by the atomicity numeral iv placed to the left of the symbol, whilst the analogous union of three bonds of each atom of iron in ferric chloride is expressed by the three dashes " to the left of the symbol Fe_3 . I shall not, however, use these coefficients of latent atomicity in the case of the single atom of an element, the student being supposed to have made himself acquainted

with the absolute atomicity of every element as expressed in the Table at page 32. For a similar reason, it will also rarely be necessary to express the same idea in graphic notation: thus, for instance, ammonia will be drawn



It will be necessary, however, to employ these coefficients in symbolic formulæ where two or more atoms of the same element are joined together under such circumstances that the number of bonds uniting them cannot be found by subtracting the coefficient of active atomicity from the absolute atomicity of the element; as in hydric persulphide ($'\text{S}'_2\text{H}_2$), for instance, which might otherwise be viewed as $'''\text{S}'_2\text{H}_2$, or $'\text{S}'_2\text{H}_2$.

In rare cases, in which oxygen links together two elements or radicals in the same line of a formula, a hyphen is placed before and after the symbol O, thus:—



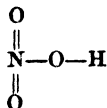
GRAPHIC NOTATION.—This mode of notation, although far too cumbrous for general use, is invaluable for clearly showing the arrangement of the individual atoms of a chemical compound. It is true that it expresses nothing more than the symbolic notation of the same compound, if the latter be written and understood as above described; nevertheless the graphic form affords most important assistance, both in fixing upon the mind the true meaning of symbolic formulæ, and also in making comparatively easy of comprehension the probable internal arrangement of the very complex molecules frequently met with both in mineral and organic compounds. It is also of especial value in rendering strikingly evident the causes of isomerism in organic bodies; and it is now almost universally employed by chemists in describing the results of their new discoveries.

Graphic notation, like the above method of symbolic notation, is founded essentially upon the doctrine of atomicity, and consists in representing, graphically, the mode in which every bond in a chemical compound is disposed of. Inasmuch, however, as the principles involved are precisely the same as those already described under the heads of SYMBOLIC NOTATION and ATOMICITY OF ELEMENTS, it is unnecessary here to do more than give the following comparative examples of symbolic and graphic formulæ:—

	Symbolic.	Graphic.
Water	OH_2 .	$\text{H}-\text{O}-\text{H}$
Nitric acid	NO_2Ho .	$\begin{array}{c} \text{O} \\ \\ \text{N}-\text{O}-\text{H} \\ \\ \text{O} \end{array}$
Ammonic chloride	NH_4Cl .	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{N}-\text{Cl} \\ / \quad \backslash \\ \text{H} \quad \text{H} \end{array}$
Sulphuric anhydride	SO_3 .	$\begin{array}{c} \text{O} \\ \\ \text{S}=\text{O} \\ \\ \text{O} \end{array}$
Sulphuric acid	SO_3Ho_2 .	$\begin{array}{c} \text{O} \\ \\ \text{H}-\text{O}-\text{S}-\text{O}-\text{H} \\ \\ \text{O} \end{array}$
Carbonic anhydride.....	CO_2 .	$\text{O}=\text{C}=\text{O}$
Potassic carbonate	COKo_2 .	$\text{K}-\text{O}-\text{C}-\text{O}-\text{K}$

Symbolic.	Graphic.
Marsh-gas..... CH_4 .	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array} $
Ammonic carbonate, COAmo_2 .	$ \begin{array}{c} \text{H} \quad \text{H} \qquad \qquad \text{H} \quad \text{H} \\ \quad \qquad \quad \quad \\ \text{H}-\text{N}-\text{O}-\text{C}-\text{O}-\text{N}-\text{H} \\ \qquad \qquad \quad \qquad \quad \\ \text{H} \qquad \qquad \quad \text{O} \qquad \qquad \text{H} \end{array} $
Zincic nitrate $\left. \begin{array}{c} \text{NO}_2\text{O} \\ \text{Zn}'' \\ \text{NO}_2\text{O} \end{array} \right\}$.	$ \begin{array}{c} \text{O} \qquad \qquad \text{O} \\ \qquad \qquad \\ \text{N}-\text{O}-\text{Zn}-\text{O}-\text{N} \\ \qquad \qquad \\ \text{O} \qquad \qquad \text{O} \end{array} $

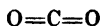
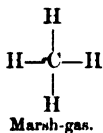
It must be carefully borne in mind that these graphic formulæ are intended to represent neither the shape of the molecules, nor the supposed relative position of the constituent hypothetical atoms. The lines connecting the different atoms of a compound, and which might with equal propriety be drawn in any other direction, provided they connected together the same elements, serve only to show the definite disposal of the bonds, the latter again being only a concrete symbolic expression of an abstract train of reasoning: thus the formula for nitric acid indicates that two of the three constituent atoms of oxygen are combined with nitrogen alone, and are consequently united to that element by both their bonds, whilst the third oxygen atom is combined both with nitrogen and hydrogen.



The lines connecting the different atoms of a compound are but crude symbols of the bond of union between them; and it is scarcely necessary to remark that no such material connexions exist, the bonds which actually hold together the constituents of a compound being, as regards their nature, entirely unknown.

It deserves also to be here mentioned that graphic, like symbolic formulæ, are purely statical representations of chemical

compounds; they take no cognizance of the amount of potential energy associated with the different elements. Thus in the formulæ for marsh-gas and carbonic anhydride,



Carbonic anhydride.

there is no indication that the molecule of the first compound contains a vast store of force, whilst the last is comparatively a powerless molecule.

CHAPTER IV.

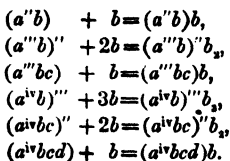
COMPOUND RADICALS.

THE term compound radical may be applied to any group of two or more atoms, which takes the place and performs the functions of an element in a chemical compound. In practice, however, it is only applied to any such group when the latter is met with in numerous chemical compounds.

An element is a *simple radical*, and enters into combination in the following manner (a , b , c , and d being monad elements, a'' a dyad, a''' a triad, and a^{iv} a tetrad element):—

$$\begin{aligned} a + b &= ab, \\ a'' + 2b &= a''b_2, \\ a''' + 3b &= a'''b_3, \\ &\&c. \quad \&c. \end{aligned}$$

A group of elements replacing a , a'' , or a''' in the above equations is a *compound radical*, as in the following examples:—



The group of elements $(a''b)$ constitutes a compound monad radical equivalent to one atom of hydrogen or chlorine. The group $(a'''b)''$ is a compound dyad radical, &c. It is therefore evident that a polyad element is essential to every compound radical; in fact *a compound radical consists of one or more atoms of a polyad element in which one or more bonds are unsatisfied; and it is either a monad, dyad, triad, &c. radical, according to the number of monad atoms required to satisfy its active atomicity.* Such a radical, when a monad, triad, or pentad, cannot exist as a separate group; like hydrogen or nitrogen, when isolated, it combines with itself, forming a duplex molecule. It is only by the union of two atoms or groups of atoms that the vacated bonds can in these cases be satisfied.

From the above definition of a compound radical, it is evident that an almost infinite number of such bodies must exist; for in the compounds of every polyad element it is only necessary to vacate successive bonds to create each time a new compound radical. Thus marsh-gas CH_4 minus one atom of hydrogen gives the compound radical methyl CH_3 ; minus two atoms of hydrogen, it forms methylene $(\text{CH}_2)''$; and by the abstraction of three hydrogen atoms it is transformed into the triad radical formyl $(\text{CH})'''$; but, except in a few cases, it is not advantageous thus to incorporate, as it were, compound radicals, which, instead of simplifying notation and nomenclature, would, if thus multiplied, only embarrass them. No compound radical, therefore, ought to receive recognition as such, unless it can be shown to enter into the composition of a large number of compounds.

The following are the names, symbols, and formulæ of the

chief inorganic compound radicals recognized in the notation of this book:—

	Molecular formulæ.	Semimolecular formulæ.	Semimolecular symbols.
Hydroxyl	$(HO)_2$	HO	Ho.
Hydrosulphyl	$(HS)_2$	HS	Hs.
Ammonium	$(NH_4)_2$	NH_4	Am.
Ammonoxyl	$(NH_4O)_2$	NH_4O	Amo.
Amidogen	$(NH_2)_2$	NH_2	Ad.

In addition to these, certain compounds which metals form with oxygen are also regarded as compound radicals—for instance,

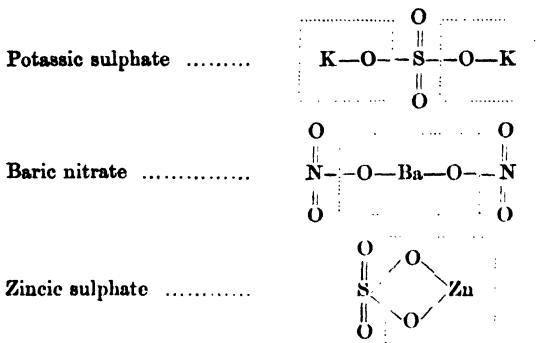
	Molecular formulæ.	Semimolecular or combining formulæ.	Semimolecular or combining symbols.
Potassoxyl.....	$(KO)_2$	KO	Ko.
Zincoxyl	(ZnO_2)	$\begin{Bmatrix} O \\ Zn'' \\ O \end{Bmatrix}$	Zno''.

The essential character of these last compound radicals is that the whole of the oxygen they contain is united with the metal by one bond only of each oxygen atom, as seen in the following graphic formulæ:—

Hydroxyl	—O—H
Potassoxyl	—O—K
Zincoxyl	—O—Zn—O—

The metal thus becomes linked to other elements by these dyad atoms of oxygen. The functions of such compound radicals will be sufficiently evident from the following examples of compounds into which they enter, and in which their position is marked by dotted lines.



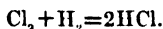


It is not necessary to dignify all these metallic compound radicals with names; the chief point of importance about them is their abbreviated notation, in which the small letter o is attached to the symbol of the metal, the atomicity of the radical being marked in the usual manner. Although the small letter o in these symbols of combining quantities has no more reference to the composition of the radical than the d in the corresponding symbol of amidogen, yet it may usefully remind the reader that oxygen is always a constituent of the compound radicals so symbolized. It must be borne in mind that the number of atoms of oxygen in any radical of this class depends upon its atomicity: thus a monad contains only one atom of oxygen, a dyad two, and a triad always three atoms of oxygen. The use of any but monad and dyad metallic compound radicals is very rare.

CHAPTER V.

ATOMIC AND MOLECULAR COMBINATION.

In all the cases of chemical combination considered in the above Chapters, a union of atoms has been invariably contemplated. This atomic union is generally attended by the breaking up of previously existing molecules—two such molecules, by the mutual exchange of their atomic constituents, producing two new and perfectly distinct molecules. Thus when chlorine unites with hydrogen to form hydrochloric acid, a molecule of chlorine and one of hydrogen yield up their constituent atoms, forming two molecules of hydrochloric acid,



In comparatively rare cases, two molecules combine to form only one new molecule; thus a molecule of carbonic oxide and one of chlorine combine to form one molecule of carbonic oxydichloride or phosgene gas: but the union is even here essentially atomic; for after combination both the oxygen and chlorine are directly united with the atom of carbon:



Chemists are, however, compelled to admit an entirely different kind of union, which not unfrequently occurs, and which in conformity with the atomic hypothesis, may be appropriately termed *molecular union* or *molecular combination*. In the formation of such compounds, no change takes place in the active atomicity of any of the molecules. It is this kind of combination which holds together salts and their water of crystallization, as, for instance,

Sodic chloride crystallized at $-10^\circ \text{C}.$ $\text{NaCl}, 2\text{OH}_2$.
 Sodic bromide crystallized below $+30^\circ \text{C}.$... $\text{NaBr}, 2\text{OH}_2$.
 Sodic iodide crystallized below $+50^\circ \text{C}.$... $\text{NaI}, 2\text{OH}_2$.
 Alum $\text{S}_2\text{O}_3(\text{Al}^{\text{iii}})_2\text{O}_9 \cdot 24\text{H}_2\text{O}$.

Numerous other instances of molecular combination might be adduced ; but it is only necessary here to point out that such molecular unions will be distinguished from atomic combinations by the use of the comma, as in the above and following examples :

Tetramethylammonic tri-iodide**NMe₄ I, I₂.**

Tetramethylammonic pentiodide**NMe₄ I, 2I₂.**

Tetramethylammonic iodo-dichloride **NMe₄ I, Cl₂.**

In all cases molecular combination seems to be of a much more feeble character than atomic union ; for, in the first place, such bodies are generally decomposed with facility ; and secondly, the properties of their constituent molecules are markedly perceptible in the compounds. Thus the above so-called periodides of the organic bases greatly resemble iodine in appearance.

CHAPTER VI.

CLASSIFICATION OF ELEMENTS.

It has already been mentioned that the elements may be divided into two great classes, the metals and the non-metals or metalloids. A second division into positive and negative elements has also been explained. A third and still more important classification is founded upon the atomicity of the elements. In the following classified Table all three methods are embodied, the metalloids being printed in red type, and the metals in black, whilst the positive elements are printed in Roman characters, and the negative in italics. In addition,

the different classes are also divided into sections, consisting of elements closely related in their chemical characters.

Monads.	Dyads.	Triads.	Tetrads.	Pentads.	Hexads.
1st Section. Hydrogen.	1st Section. <i>Oxygen</i> .	1st Section. Boron.	1st Section. Carbon. Silicon. Tin.	1st Section. Nitrogen. Phosphorus. Vanadium. Arsenic. Antimony. Bismuth.	1st Section. Sulphur. Selenium. Tellurium.
2nd. Section. <i>Fluorine</i> . <i>Chlorine</i> . <i>Bromine</i> . <i>Iodine</i> .	2nd Section. Barium. Strontium. Calcium. Magnesium. Zinc.	2nd Section. Gold.	2nd Section. Titanium. Thorium. Niobium. Tantalum. Zirconium. Aluminium. Indium.		2nd Section. Tungsten. Molybdenum.
3rd Section. Cædium. Rubidium. Potassium. Sodium. Lithium.	3rd Section. Didymium. Lanthanum. Yttrium. Glucinum.	3rd Section. Thallium.	3rd Section. Platinum. Palladium.		3rd Section. Osmium. Iridium. Ruthenium. Rhodium.
4th Section. Silver.	4th Section. Cadmium. Mercury. Copper.		4th Section. Lead.		4th Section. Chromium. Manganese. Iron. Cobalt. Nickel. Uranium. Cerium.

CHAPTER VII.

WEIGHTS AND MEASURES.

THE weights and measures employed in this book are chiefly those of the French decimal system, founded upon the metre, which is $\frac{1}{10,000,000}$ th part of a quadrant of a great terrestrial circle. The following Tables, published by Messrs. De La Rue and Co., will enable the student to convert these into their English equivalents whenever it may be necessary.

French Measures of Length.

	In English inches.	In English feet = 12 inches.	In English yards = 3 feet.	In English fathoms = 6 feet.	In English miles = 1760 yards.
Millimètre	0.03937	0.003281	0.0010936	0.0005408	0.0000066
Centimètre	0.39371	0.032808	0.0109363	0.0054082	0.0000662
Décimètre	3.93708	0.328080	0.1093633	0.0540816	0.0006621
Mètre	39.37079	3.280800	1.0936331	0.5408165	0.0066213
Décamètre	393.70790	32.808002	10.9363310	5.4081655	0.0662138
Hectomètre	3937.07900	328.080020	109.3633100	54.0816550	0.6621382
Kilomètre	39370.79000	3280.800200	1093.6331000	540.8165500	0.6213824
Myriomètre	393707.90000	32808.002000	10936.3310000	5408.1655000	6.2138244
1 inch = 2.539954 centimètres. 1 foot = 30.479440 decimètres.			1 yard = 0.914385 mètre. 1 mile = 1.609344 kilomètre.		

French Measures of Surface.

	In English square feet.	In English square yards = 9 square feet.	In English poles = 272.25 sq. feet.	In English roods = 1080 sq. feet.	In English acres = 43560 sq. feet.
Centiare or sq. mètre	10.764226	1.196003	0.0045783	0.0008855	0.0002471
Are or 100 sq. mètres	1076.422634	119.600326	0.45783290	0.0088457	0.0247114
Hectare or 10,000 square mètres	107642.266418	11960.032622	45.78329050	0.08845724	2.4711431
1 square inch = 6.4515999 square centimètres. 1 square foot = 9.2903043 square decimètres. 1 square yard = 0.8361273 square mètre or centiare. 1 acre = 0.40468564 hectare.					

French Measures of Capacity.

	In cubic inches.	In cubic feet = 1728 cubic inches.	In pints = 34.65923 cubic inches.	In gallons = 7.757674 cubic inches.	In bushels = 8 gallons = 221.93675 cubic inches.
Millilitre or cubic cen- timètre	0.06103	0.000023	0.00176	0.0002201	0.0000275
Centilitre or 10 cubic centimètres	0.61027	0.000353	0.01761	0.0022010	0.0002751
Déclilitre or 100 cubic centimètres	6.10271	0.003532	0.17608	0.0220097	0.0027512
Litre or cubic décimètre	61.02705	0.035317	1.76077	0.2200967	0.0275121
Décalitre or centistère	610.27052	0.353166	17.60773	2.2009668	0.2751208
Hectolitre or décastère	6102.70515	3.531658	176.07734	22.0096677	2.7512086
Kilolitre, or Stère, or cubic mètre	61027.05152	35.316581	1760.77341	220.0966767	27.5120846
Myriolitre or décastère	610270.51519	353.165807	17607.73411	2200.9667675	275.1208459
1 cubic inch = 16.386176 cubic centimètres. 1 cubic foot = 28.315312 cubic décimètres, or litres. 1 gallon = 4.543352 litres.					

French Measures of Weight.

	In English grains.	In Troy ounces= 480 grains.	In avoirdupois lbs.= 7000 grains.	In cwt.= 112 lbs.= 784000 gra.	Ton= 20 cwt.= 1680000 gra.
Milligramme	0.01543	0.00032	0.000022	0.000000	0.000000
Centigramme	0.15432	0.00322	0.000220	0.000002	0.000000
Décigramme	1.54323	0.03215	0.002205	0.000020	0.000001
Gramme	15.43235	0.32151	0.022046	0.000197	0.000010
Déca gramme	154.32349	3.21507	0.220462	0.001968	0.000098
Héctogramme	1543.23488	32.15073	2.204621	0.019684	0.000968
Kilogramme	15432.34880	321.50727	22.046213	0.196841	0.009684
Myriogramme	154323.48800	3215.07267	220.462126	1.968412	0.029684
1 grain	= 0.064792 gramme.		1 lb. avoirdupois = 0.453593 kilogr.		
1 troy oz.	= 31.103496 grammes.		1 cwt. = 50.802377 kilogr.		
1 métrekilogramme =	7.2324 foot lbs.				

Temperatures are expressed upon the Centigrade scale; and barometric measurements are given in millimetres.

For the ready conversion of gaseous volumes into weights, I have adopted the *crith*, or standard multiple proposed by Dr. Hofmann. The *crith* is the weight of one litre, or cubic decimetre, of hydrogen at 0° C. and at a pressure of 760 millimetres of mercury. The following is Dr. Hofmann's description of the value and applications of this unit.

“The actual weight of this cube of hydrogen, at the standard temperature and pressure mentioned, is 0.0896 gramme; a figure which I earnestly beg you to inscribe, as with a sharp graving tool, upon your memory. There is probably no figure in chemical science more important than this one to be borne in mind, and to be kept ever in readiness for use in calculation at a moment's notice. For this litre-weight of hydrogen = 0.0896 gramme (I purposely repeat it) is the standard multiple, or coefficient, by means of which the weight of one litre of any other gas, simple or compound, is computed. Again, therefore, I say, do not let slip this figure—0.0896 gramme. So important, indeed, is this standard weight unit, that some name—the simpler and briefer the better—is needed to denote it. For this purpose I venture to suggest the term *crith*, derived from the Greek word *κριθῆ*, signifying a barley-corn, and figuratively employed to imply a small weight. The weight of 1 litre of hydrogen being called 1 *crith*, the volume-weight

of other gases, referred to hydrogen as a standard, may be expressed in terms of this unit.

“For example, the relative volume-weight of chlorine being 35·5, that of oxygen 16, that of nitrogen 14, the actual weight of 1 litre of each of these elementary gases, at 0° C. and 0^m·76 pressure, may be called respectively 35·5 *criths*, 16 *criths*, and 14 *criths*.

“So, again, with reference to the compound gases; the relative volume-weight of each is equal to half the weight of its product-volume. Hydrochloric acid (HCl), for example, consists of 1 vol. of hydrogen + 1 vol. of chlorine = 2 volumes; or, by weight, 1 + 35·5 = 36·5 units; whence it follows that the relative volume-weight of hydrochloric acid gas is $\frac{36\cdot5}{2} = 18\cdot25$ units; which last figure therefore expresses the number of *criths* which one litre of hydrochloric acid gas weighs at 0° C. temperature and 0^m·76 pressure; and the crith being (as I trust you already bear in mind) 0·0896 gramme, we have

$$18\cdot25 \times 0\cdot0896 = 1\cdot6352$$

as the actual weight in grammes of hydrochloric acid gas.

“So, once more, as the product-volume of water-gas (H₂O) (taken at the above temperature and pressure) contains 2 vols. of hydrogen + 1 vol. of oxygen, and therefore weighs 2 + 16 = 18 units, the single volume of water-gas weighs $\frac{18}{2} = 9$ units; or, substituting as before the concrete for the abstract value, 1 litre of water-gas weighs 9 *criths*; that is to say, $9 \times 0\cdot0896$ gramme, = 0·8064 gramme.

“In like manner the product-volume of sulphuretted hydrogen (H₂S) = 2 litres of hydrogen, weighing 2 *criths*, + 1 litre of sulphur-gas, weighing 32 *criths*, together 2 + 32 = 34 *criths*, which, divided by 2, gives $\frac{34}{2} = 17$ *criths* = $17 \times 0\cdot0896$ gramme = 1·5232 gramme = the weight of 1 litre of sulphuretted hydrogen at standard temperature and pressure.

“And so, lastly, of ammonia (NH₃); it contains in 2 litres 3 litres of hydrogen, weighing 3 *criths*, and 1 litre of nitrogen, weighing 14 *criths*; its total product-volume-weight is there-

fore $3+14=17$ criths, and its single volume or litre weight is consequently

$$\frac{17}{2}=8.5 \text{ criths}=8.5 \times 0.0896 \text{ gramme}=0.7616 \text{ gramme.}$$

"Thus, by the aid of the hydrogen-litre-weight or *crith* $=0.0896$ gramme, employed as a common multiple, the actual or concrete weight of 1 litre of any gas, simple or compound, at standard temperature and pressure, may be deduced from the mere abstract figure expressing its volume-weight relatively to hydrogen."

The number expressing in criths the weight of 1 litre of any gas or vapour being identical with its specific gravity compared with hydrogen taken as unity, it is easy, when this number is known, to calculate the specific gravity of the gas compared with air taken as unity. For this purpose it is only necessary to multiply by $.0693$, which is the specific gravity of hydrogen compared with air $=1$.

Thus the specific gravity of oxygen compared with air is

$$16 \times .0693 = 1.1088;$$

of chlorine,

$$35.5 \times .0693 = 2.46015;$$

of hydrochloric acid,

$$18.25 \times .0693 = 1.264725.$$

CHAPTER VIII.

MONAD ELEMENTS.

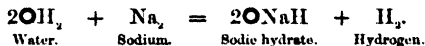
SECTION I.

HYDROGEN, H_2 .

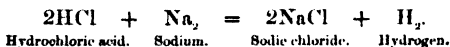
Atomic weight = 1. Molecular weight = 2. Molecular volume
 $\square\square$. 1 litre weighs 1 crith. *Atomicity', being the standard of comparison.*

Occurrence.—In combination, as water, in very large quantities in nature. In almost all vegetable and animal substances, and in many minerals. In the free state in the gases of volcanoes. In the sun, certain stars, and nebulae.

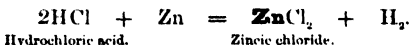
Preparation.—1. By the action of sodium upon water :—



2. By the action of sodium upon dry hydrochloric acid :—



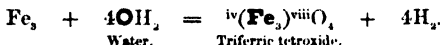
3. By the action of zinc, iron, or certain other metals on hydrochloric acid :—



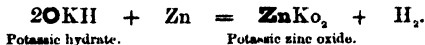
4. By the action of zinc, or certain other metals on dilute sulphuric acid :—



5. By passing steam over iron heated to redness :—



6. By the action of zinc on a boiling solution of potassic hydrate :—



7. By the electrolysis of water and of some other liquids containing hydrogen.

8. By the action of intense heat upon water.

9. In the destructive distillation of some organic substances.

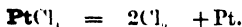
SECTION II.

CHLORINE, Cl_2 .

Atomic weight = 35.5. *Molecular weight* = 71. *Molecular volume* $\square\square$. 1 litre weighs 35.5 grs. *Has not been solidified.*
Liquefies at $15^{\circ}\cdot 5$ C., *under a pressure of* 4 atmospheres.
Atomicity '. *Evidence of atomicity*, HCl .

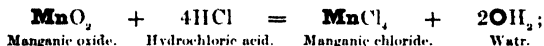
Occurrence.—Always in combination—with sodium and other metals in sea-water, and in the solid state in the salt-beds of Cheshire, Worcester, &c. Evolved from volcanoes in the form of hydrochloric acid.

Preparation.—1. By heating certain metallic chlorides, as platinic and auric chlorides:—



Platinic chloride.

2. By gently heating a mixture of manganic oxide and hydrochloric acid, when the reaction takes place in two stages:—

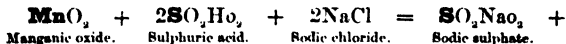


Manganic oxide. Hydrochloric acid. Manganic chloride. Water.

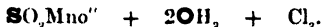


Manganic chloride. Manganous chloride.

3. By heating a mixture of sulphuric acid, sodic chloride, and manganic oxide, when the whole of the chlorine present is liberated:—



Manganic oxide. Sulphuric acid. Sodic chloride. Sodic sulphate.

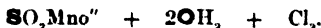


Manganous sulphate. Water.

If in the second process a mixture of manganic oxide, hydrochloric acid, and sulphuric acid be employed, the whole of the chlorine is evolved:—



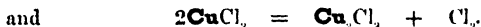
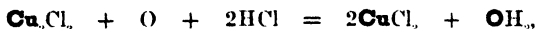
Manganic oxide. Sulphuric acid. Hydrochloric acid.



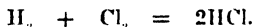
Manganous sulphate. Water.

4. By the electrolysis of hydrochloric acid.

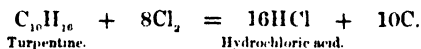
5. Cuprous chloride, heated in air and moistened with hydrochloric acid or, heated in a current of hydrochloric acid gas, steam and air, produces cupric chloride. By raising the temperature chlorine is evolved, and cuprous chloride reproduced:—



Reactions.—1. Chlorine and hydrogen, when mixed, unite instantly, with explosion, under the influence of sunlight, or of powerful artificial light, or on the application of a burning body to the mixture. An igniting jet of hydrogen continues to burn when plunged into chlorine:



2. Chlorine has so great an attraction for hydrogen, that it removes the latter from its compounds with carbon. When a rag moistened with turpentine is plunged into chlorine, the chlorine and hydrogen unite, with evolution of heat and light, carbon being liberated:—



HYDROCHLORIC ACID, *Chlorhydric Acid*, *Muriatic Acid*.

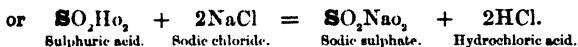
HCl.

Molecular weight = 36·5. *Molecular volume* $\square\square$. 1 litre weighs 18·25 criths. Has not been solidified. Condenses at 10°, under a pressure of 40 atmospheres.

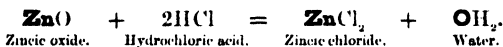
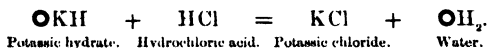
Occurrence.—Evolved from volcanoes.

Preparation.—1. From its elements, as above described.

2. By gently heating sodic chloride with sulphuric acid, previously diluted with a small quantity of water:—



Reactions.—Hydrochloric acid may be converted into salts, termed chlorides, by the action of certain metals, as described above, and also by that of the metallic hydrates, or oxides:—



For the remaining monad elements of this Section, see Chapter XIV.

CHAPTER IX.

DYAD ELEMENTS.

SECTION I.

OXYGEN, O₂.

Atomic weight=16. *Molecular weight*=32. *Molecular volume* . 1 litre weighs 16 grths. *Atomicity*". *Evidence of atomicity* :—

Water	OH ₂ .
Potassic hydrate	OKH.
Argentio oxide	OAg ₂ .
Hypochlorous anhydride	OCl ₂ .

Occurrence.—In the free state, in the atmosphere. In the combined state, in water, in most mineral bodies, and in almost all animal and vegetable compounds.

Preparation.—1. If metallic mercury be heated to its boiling-

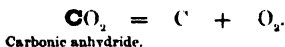
point with access of air, it gradually absorbs oxygen, being converted into mercuric oxide, $\text{Hg}''\text{O}$. This compound, when more strongly heated, is resolved into its elements,



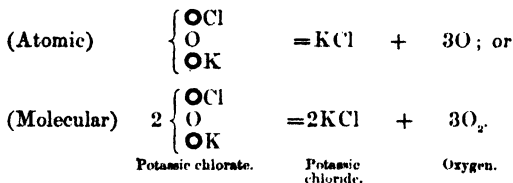
2. By heating native manganic oxide (pyrolusite), a portion of its oxygen is liberated :—



3. Oxygen is evolved in nature, in a remarkable manner, by the decomposition of carbonic anhydride, CO_2 , by the green leaves of plants, the vegetable assimilating the carbon, whilst the oxygen escapes into the atmosphere :—

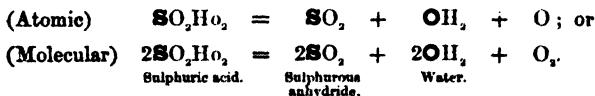


4. By the action of heat upon potassic chlorate :—



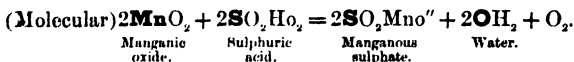
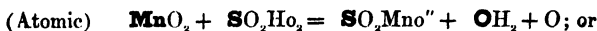
5. By mixing the potassic chlorate with manganic oxide, the oxygen is evolved at a much lower temperature; the manganic oxide appears to take no part in the reaction.

6. By dropping concentrated sulphuric acid into a red-hot platinum retort, the acid is decomposed into oxygen, sulphurous anhydride, and water :—

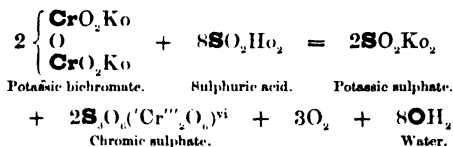


7. By the electrolysis of dilute sulphuric acid.

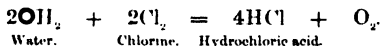
8. By the action of heat upon a mixture of manganic oxide and sulphuric acid :—



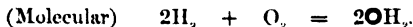
9. By heating a mixture of potassic bichromate and sulphuric acid :—



10. By passing steam and chlorine through a red-hot porcelain tube, hydrochloric acid and oxygen are formed :—



Reaction.—A mixture of two volumes of hydrogen and one volume of oxygen explodes at a red heat, water being produced. The same compound is formed when hydrogen is burnt in oxygen, or oxygen in hydrogen :—



ALLOTROPIC OXYGEN, or OZONE, O_3 .

Molecular weight = 48. *Molecular volume* $\square\square$. 1 litre weighs 24 criths.

Preparation.—1. When electric sparks are passed through air, or oxygen, a peculiar odour, which is due to ozone, is observed.

2. By placing phosphorus for a few hours in moist air, at about the ordinary temperature.

3. By passing an electric current through dilute sulphuric or chromic acid.

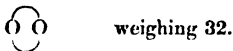
Thus obtained, ozone is always mixed with a large proportion of air, or oxygen.

Properties.—Powerfully oxidizing. It oxidizes organic matter, silver, and mercury at the ordinary temperature. When oxygen is converted into ozone, contraction of volume takes place; and when the ozone is heated to 290° , it is retransformed into the original volume of ordinary oxygen,—indicating that the molecule of ozone contains more atoms than the molecule of ordinary oxygen.

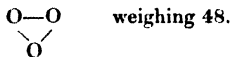
In most cases of oxidation by ozone no diminution of the volume of gas takes place, the additional atoms, previously introduced into the molecules of oxygen, being removed, and ordinary oxygen becoming free. But oil of turpentine absorbs the whole molecule of the ozone, leaving untouched the oxygen which was previously present in the state of admixture. By observing the contraction during its production, and the diminution of volume produced by absorbing the ozone with oil of turpentine, its density may be readily calculated, and consequently its atomic constitution.

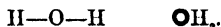
By this means the specific gravity of ozone has been shown to be 24, the molecular weight being therefore 48, which is the weight of 3 atoms of oxygen.

In ordinary oxygen, the molecule is composed of two atoms of oxygen, and is represented by



In ozone, the molecule contains 3 atoms of oxygen, and is represented by



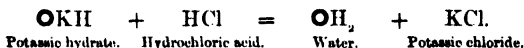
WATER, Hydric Oxide.

Molecular weight = 18. *Molecular volume* $\square\square$. 1 litre of water-vapour weighs 9 criths. *Melts* at 0° . *Boils* at 100° .

Occurrence.—Very abundantly in nature.

Formation.—1. By the direct union of hydrogen and oxygen, as already described.

2. As a secondary product, in numberless chemical reactions, as, for instance, in the action of hydrochloric acid on potassic hydrate :—



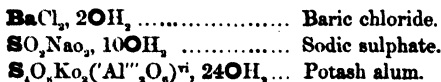
Reactions.—1. By its action many metallic oxides are converted into hydrates :—

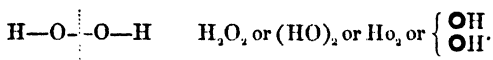


2. It transforms anhydrides into acids :—



3. It also unites molecularly with many compounds, as water of crystallization (see Chapter V.), as in the following instances :—



HYDROXYL, Hydric Peroxide.

Probable molecular weight = 34.

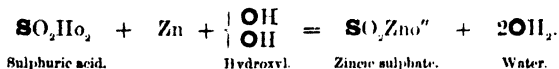
Preparation.—By passing a current of carbonic anhydride through water in which baric peroxide is suspended:—



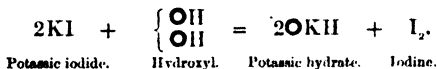
Reactions.—1. By heat it is decomposed into water and oxygen:—



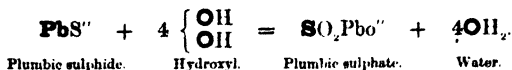
2. Hydroxyl is transformed into water by the action of nascent hydrogen: if hydroxyl be introduced into an apparatus in which hydrogen is being generated, the gas ceases to be evolved:—



3. Hydroxyl liberates iodine from potassic iodide:—



4. Hydroxyl is a powerful oxidizing agent; it converts, for instance, plumbic sulphide into plumbic sulphate:—



**COMPOUNDS OF CHLORINE WITH OXYGEN
AND HYDROXYL.**

Oxygen forms many compounds with chlorine and with chlorine and hydroxyl; but none of them can be produced by direct combination. The following list contains all that are known:—

Hypochlorous anhydride	$\left\{ \begin{array}{l} \bullet\text{OCl}_2 \\ \bullet\text{OCl} \\ \bullet\text{OCl} \end{array} \right.$	$\text{Cl}-\text{O}-\text{Cl}$
Chloric oxide? ...	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \bullet\text{OCl} \end{array} \right.$	$\text{Cl}-\text{O}-\text{O}-\text{Cl}$
Chlorous anhydride	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \text{O} \cdot \\ \bullet\text{OCl} \end{array} \right.$	$\text{Cl}-\text{O}-\text{O}-\text{O}-\text{Cl}$
Chloric peroxide	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \text{O} \cdot \\ \text{O} \cdot \\ \bullet\text{OCl} \end{array} \right.$	$\text{Cl}-\text{O}-\text{O}-\text{O}-\text{O}-\text{Cl}$
Chloric hyperoxide?	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \text{O} \cdot \\ \text{O} \cdot \\ \text{O} \cdot \\ \text{O} \cdot \\ \bullet\text{OCl} \end{array} \right.$	$\text{Cl}-\text{O}-\text{O}-\text{O}-\text{O}-\text{O}-\text{O}-\text{Cl}$
Hypochlorous acid, $\bullet\text{OClH}$, or ClHO .		$\text{H}-\text{O}-\text{Cl}$
Chlorous acid... $\bullet\text{OClHo}$, or	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \bullet\text{OH} \end{array} \right.$	$\text{H}-\text{O}-\text{O}-\text{Cl}$
Chloric acid... $\left\{ \begin{array}{l} \bullet\text{OCl} \\ \bullet\text{OHo} \end{array} \right.$, or	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \text{O} \cdot \\ \bullet\text{OH} \end{array} \right.$	$\text{H}-\text{O}-\text{O}-\text{O}-\text{Cl}$
Perchloric acid $\left\{ \begin{array}{l} \bullet\text{OCl} \\ \text{O} \cdot \\ \bullet\text{OHo} \end{array} \right.$, or	$\left\{ \begin{array}{l} \bullet\text{OCl} \\ \text{O} \cdot \\ \text{O} \cdot \\ \bullet\text{OH} \end{array} \right.$	$\text{H}-\text{O}-\text{O}-\text{O}-\text{O}-\text{Cl}$

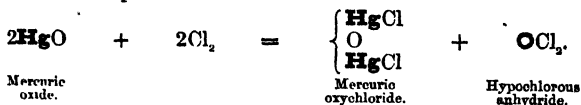
OXIDES OF CHLORINE.

HYPOCHLOROUS ANHYDRIDE.



Molecular weight = 87. *Molecular volume* $\square\square$. *1 litre of hypochlorous anhydride vapour weighs 48.5 criths. Boils at about 20°.*

Preparation.—By passing chlorine over dry mercuric oxide, at a low temperature :—

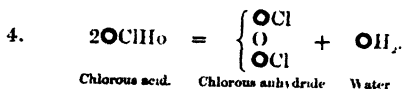
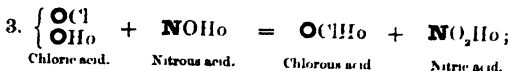
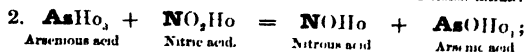
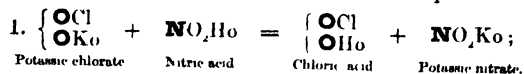


CHLOROUS ANHYDRIDE.



Molecular weight = 119. *Molecular volume anomalous* $\square\square\square$. *1 litre weighs 39.7 criths.*

Preparation.—By gently heating in a water-bath a mixture of potassic chlorate, nitric acid, and arsenious acid. Four different reactions are to be distinguished in this operation :—

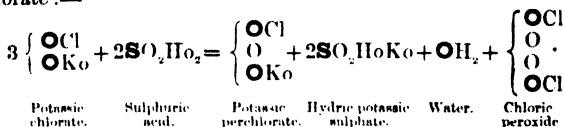


CHLORIC PEROXIDE.



Molecular weight = 135. *Boils at* 20°.

Preparation.—By the action of sulphuric acid on potassic chlorate :—



HYPOCHLOROUS ACID.

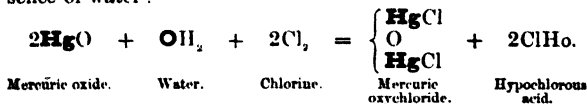


Molecular weight = 52.5.

Preparation.—1. By the action of water on hypochlorous anhydride :—



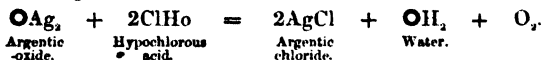
2. By the action of chlorine upon mercuric oxide, in the presence of water :—



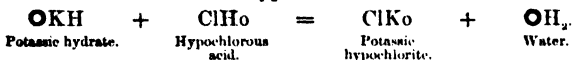
Reactions.—1. By the action of hydrochloric acid, chlorine is evolved from both the hydrochloric acid and hypochlorous acid :—



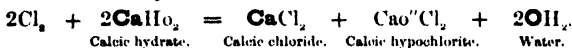
2. By the action of argentic oxide, oxygen is evolved from both compounds :—



3. By the action of hypochlorous acid, metallic oxides or hydrates are converted into hypochlorites :—



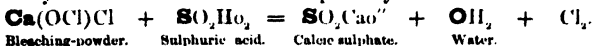
It was formerly supposed that hypochlorites, together with chlorides, were formed when chlorine acted upon certain metallic oxides and hydrates :—



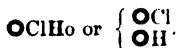
But the so-called chloride of lime or bleaching-powder does not contain calcic chloride, and the true reaction appears to be



By the action of acids this compound yields free chlorine :—



CHLOROUS ACID.

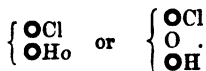


Molecular weight = 68·5.

Preparation.—By the action of water upon chlorous anhydride :—

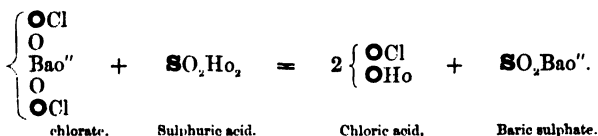


CHLORIC ACID.

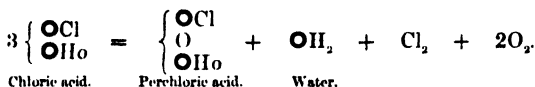


Molecular weight = 84.5.

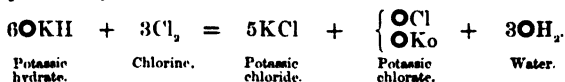
Preparation.—By the action of dilute sulphuric acid upon baric chlorate:—



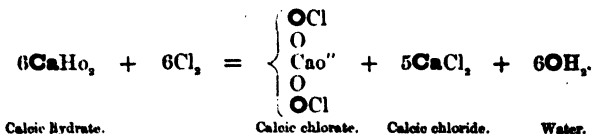
Decomposition.—By boiling, it is decomposed into perchloric acid, water, chlorine, and oxygen:—



Preparation of Chlorates.—1. Potassic chlorate may be prepared by the action of chlorine upon a concentrated solution of potassic hydrate:—

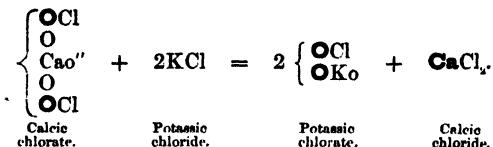


2. Calcic chlorate is made by passing chlorine through boiling milk of lime:—

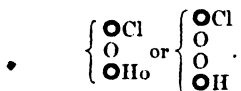


By the addition of potassic chloride to the calcic chlorate,

potassic chlorate is formed ; the latter is then separated from the calcic chloride by crystallization :—

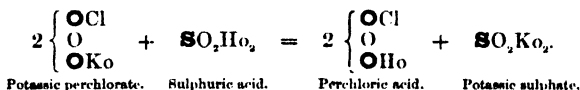


PERCHLORIC ACID.



Molecular weight = 100·5.

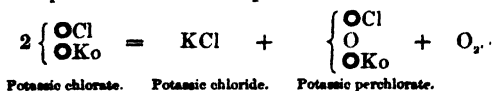
Preparation.—Potassic perchlorate is distilled with about three times its weight of sulphuric acid :—



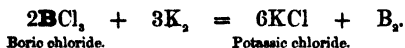
The impure perchloric acid is then carefully rectified, when pure perchloric acid passes over as an oily liquid towards the end of the operation.

It forms with water a white crystalline hydrate.

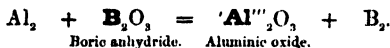
Preparation of Potassic Perchlorate.—1. Potassic chlorate is heated gradually, and the process arrested when one third of the oxygen present has been evolved ; the residue then contains potassic chloride and perchlorate :—



2. By passing boric chloride over heated potassium :—

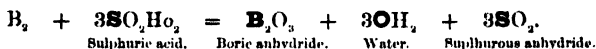


β. Diamond boron.—By fusing boric anhydride with aluminium :—

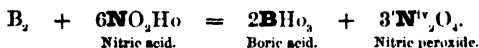


Reactions.—

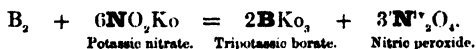
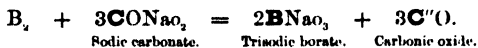
a. Amorphous boron.—1. Decomposes hot sulphuric acid :—



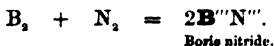
2. Decomposes nitric acid :—



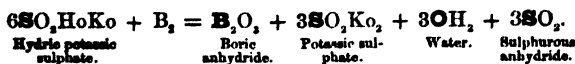
3. Decomposes alkaline carbonates, sulphates, and nitrates :—



4. Boron is one of the few elements which unite directly with nitrogen :—



β. Diamond boron.—1. When fused with hydric potassic sulphate, boric anhydride is formed :—

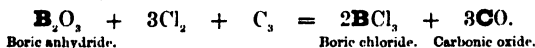


No compound of boron with hydrogen has been obtained; but the chloride, bromide, and fluoride are known.

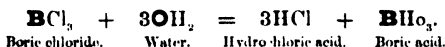
BORIC CHLORIDE.

Molecular weight = 117.5. *Molecular volume* $\square\square$. 1 litre of boric chloride vapour weighs 58.75 criths. *Sp. gr.* 1.85 at 7°. *Boils at* 17°.

Preparation.—By passing chlorine over a mixture of boric anhydride and charcoal heated to redness:—



Reaction.—In contact with water it forms hydrochloric and boric acids:—

**BORIC BROMIDE.**

Molecular weight = 251. *Molecular volume* $\square\square$. 1 litre of boric bromide vapour weighs 125.5 criths. *Sp. gr. of liquid* = 2.69. *Boils at* 90°.

Prepared and decomposed in exactly the same way as the chloride.

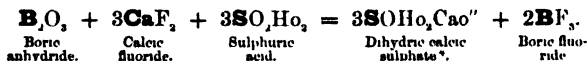
X BORIC FLUORIDE.

Molecular weight = 68. *Molecular volume* $\square\square$. 1 litre weighs 34 criths.

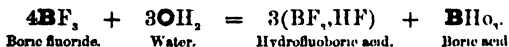
Preparation.—1. By strongly heating boric anhydride with calcic fluoride:—



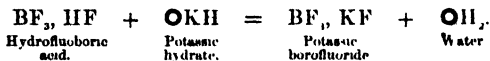
2. By heating together boric anhydride with calcic fluoride and sulphuric acid :—



Reaction.—By contact with water, boric fluoride forms a peculiar acid, the hydrofluoboric acid, the constitution of which is not well understood :—



This acid acts upon metallic hydrates, forming salts :—



Possibly the boron in these compounds is pentadic—thus, B^+HF_4^- and B^+KF_4^- .

COMPOUNDS OF BORON WITH OXYGEN AND HYDROXYL.

Boric anhydride	B_2O_3 .
Monobasic boric acid	}	BOH_3 .
Metaboric acid		
Tribasic boric acid	}	BHO_3 .
Boric acid		

BORIC ANHYDRIDE, *Boracic anhydride.*



Molecular weight = 70. *Sp. gr.* 1.83.

Preparation.—By fusing boric acid at a red heat :—



* See sulphuric acid, Chap. XIII. p. 83.

BORIC ACID, Boracic Acid, Orthoboric Acid,

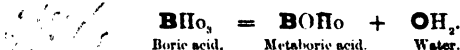
Molecular weight = 62. *Sp. gr.* 1.479.

Occurrence.—Contained in the steam which escapes from the *soffioni* in Tuscany.

Preparation.—By the addition of hydrochloric acid to a hot saturated solution of borax, when the acid crystallizes out on cooling:—

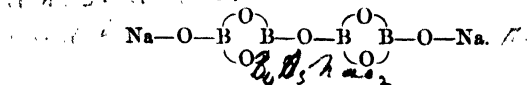
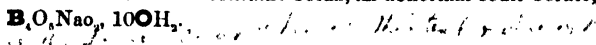


Reactions.—1. At the temperature of 100° it loses water, being converted into metaboric acid:—

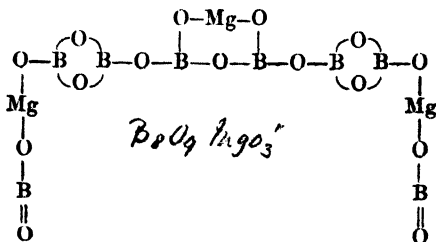


2. By the action of metallic hydrates, oxides, or carbonates, borates are formed.

The mineral *tincal* contains borax, an abnormal sodic borate,



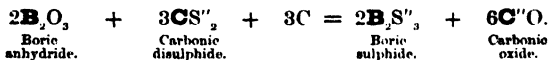
A trimagnesian octaborate is known as the mineral *boracite*:—



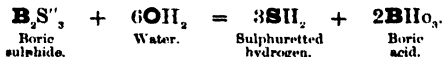
BORIC SULPHIDE. X

Molecular weight = 118.

Preparation.—By passing carbonic disulphide over a mixture of carbon and boric anhydride, heated to bright redness:—



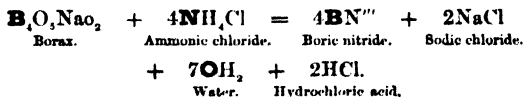
Reaction.—Boric sulphide is readily decomposed by water, giving sulphuretted hydrogen and boric acid:—

**BORIC NITRIDE.**

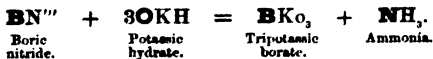
Molecular weight = 25.

Preparation.—1. By heating boron in nitrogen (see p. 53).

2. By heating together borax and ammonic chloride:—



Reaction.—When fused with potassic hydrate, boric nitride yields tripotassic borate and ammonia:—



CHAPTER XI.

TETRAD ELEMENTS.

SECTION I.

CARBON, C.

Atomic weight = 12. *Atomicity* " and " . *Evidence of atomicity* :—

Carbonic oxide.....	$\text{C}^{\text{II}}\text{O}$.
Carbonic tetrachloride...	$\text{C}^{\text{IV}}\text{Cl}_4$. <i>coal chloride</i>
Marsh-gas.....	$\text{C}^{\text{IV}}\text{H}_4$. <i>marsh gas</i>
Chloroform	$\text{C}^{\text{I}}\text{HCl}_3$. <i>chloroform</i>

Occurrence.—In large quantities in nature, but chiefly in combination.

Three varieties of carbon are known :—

a. Amorphous carbon.

Occurrence.—In small quantities in nature, as mineral charcoal.

Preparation.—1. By the action of heat on animal and vegetable matters, without access of air.

2. By the action of potassium, at a high temperature, on carbonic anhydride.

Reaction.—By treatment with a mixture of potassic chlorate and fuming nitric acid, it is converted into brown compounds soluble in water.

β. Graphite.

Occurrence.—As the mineral called plumbago.

Preparation.—1. By the action of intense heat on the diamond.

2. By dissolving charcoal in melted cast iron, and subsequent cooling, when the graphite separates in the crystalline state.

3. By heating the various forms of amorphous carbon in the electric arc.

Reaction.—By prolonged digestion with a mixture of nitric acid and potassic chlorate it is converted into *graphitic acid*, a

brown crystalline body insoluble in water. Graphitic acid, when heated in the dry state, swells up suddenly, being changed into *pyrographitic oxide*, which is dissolved by the mixture of potassic chlorate and nitric acid.

γ. Diamond.

Occurrence.—In small quantities in nature. Has not yet been obtained artificially.

Reaction.—Is not affected by a mixture of potassic chlorate and nitric acid.

COMPOUNDS OF CARBON WITH OXYGEN.

CARBONIC ANHYDRIDE.

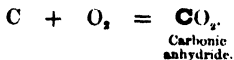


Molecular weight = 44. *Molecular volume* $\square\square$. 1 litre weighs 22 criths. *Fuses at* -57° . *Boils below its melting-point.*

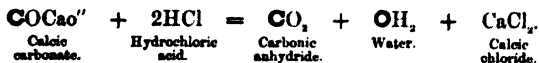
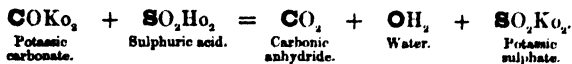
Occurrence.—In the atmosphere, and dissolved in water.

Formation.—By the combustion of carbon and of carbonaceous substances in air or oxygen. In respiration, decay, putrefaction, and fermentation. During the formation of coal. Evolved from volcanoes.

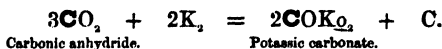
Preparation.—1. By burning carbon in air or oxygen:—



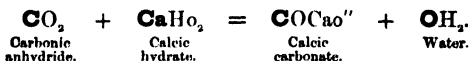
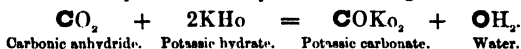
2. By the action of acids upon metallic carbonates:—



Reactions.—1. Carbonic anhydride is decomposed by heated potassium :—



2. It acts upon metallic hydrates, forming carbonates :—



Carbonic acid, COHo_2 , is not known.

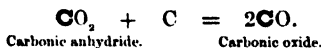
CARBONIC OXIDE.



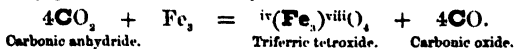
Molecular weight = 28. *Molecular volume* $\square\square$. 1 litre weighs 14 criths.

Formation.—In the combustion of carbon or carbonaceous matter, with a limited supply of air. In the destructive distillation of many organic substances containing oxygen.

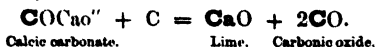
Preparation.—1. By passing carbonic anhydride over red-hot charcoal :—



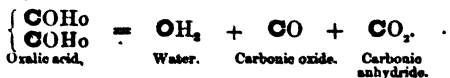
2. By passing carbonic anhydride over red-hot iron :—



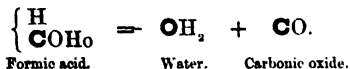
3. By heating iron or carbon with a carbonate :—



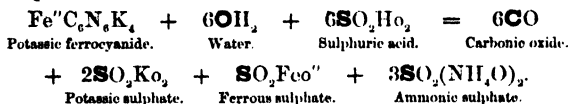
4. By heating oxalic acid with sulphuric acid (by which water is removed from the former), and then separating the carbonic anhydride by washing with sodic hydrate :—



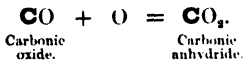
5. By heating formic acid, or a formate, with sulphuric acid:—



6. By heating potassic ferrocyanide with sulphuric acid:—



Reactions.—1. It burns in air and oxygen, producing carbonic anhydride:—



2, Carbonic oxide and chlorine unite under the influence of light (p. 30), forming *carbonic oxydichloride*, or *phosgene gas*, COCl_2 .

The compounds of carbon with chlorine, nitrogen, and hydrogen will be studied in connexion with organic compounds.

CHAPTER XII.

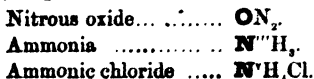
PENTAD ELEMENTS.

SECTION I.

NITROGEN, *Azote*, N_2 .

Atomic weight = 14. *Molecular weight* = 28. *Molecular volume*

$\square\square$. 1 litre weighs 14 criths. *Atomicity*°, which, by the mutual saturation of pairs of bonds, becomes reduced to ' or to ' (see p. 20). *Evidence of atomicity*:—



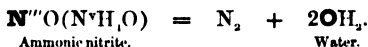
62 COMPOUNDS OF NITROGEN WITH OXYGEN AND HYDROXYL.

Occurrence.—In the free state in the atmosphere. In some nebulae? In combination, in animal and vegetable bodies, and in native nitrates.

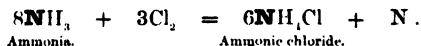
Preparation.—1. By burning phosphorus in air, whereby the oxygen is removed from the latter.

2. By passing air over ignited copper, when the oxygen unites with the copper.

3. By heating ammoniac nitrite, or a mixture of ammoniac chloride and potassic or sodic nitrite:—



4. By passing chlorine through an excess of solution of ammonia:—



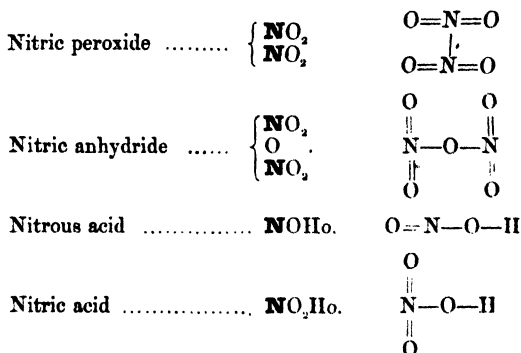
COMPOUNDS OF NITROGEN WITH OXYGEN AND HYDROXYL.

Nitrous oxide..... ON_2 . $\text{N}-\text{O}-\text{N}$

Nitric oxide*..... $\left\{ \begin{array}{l} \text{NO} \\ \text{NO} \end{array} \right.$ $\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{N}-\text{N} \end{array}$

Nitrous anhydride..... $\left\{ \begin{array}{l} \text{NO} \\ \text{O} \\ \text{NO} \end{array} \right.$ $\begin{array}{c} \text{O} \quad \quad \text{O} \\ \parallel \quad \quad \parallel \\ \text{N}-\text{O}-\text{N} \end{array}$

* This compound is anomalous; for its molecule, deduced from the specific gravity, is represented by NO. The dissociation, which in the case of $\left\{ \begin{array}{l} \text{NO}_2 \\ \text{NO}_2 \end{array} \right.$ is very imperfect at 0° C., but almost complete at 100° C., is probably nearly complete in the case of N_2O_2 at the lowest temperature to which this gas has hitherto been exposed.

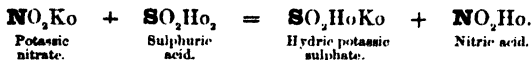
NITRIC ACID, *Aqua fortis*.

Molecular weight = 63. *Molecular volume* $\square\square$. 1 litre of nitric acid vapour weighs 31.5 criths. *Fuses at* -50° . *Boils at* 84.5° .

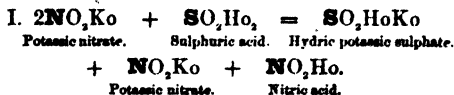
Production.—1. By the slow oxidation of nitrogenized organic matter, in the presence of powerful bases.

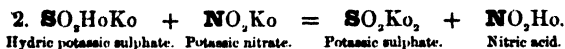
2. By the passage of electric sparks through moist air.

Manufacture.—By distilling potassic nitrate (nitre), or sodic nitrate (cubic nitre), with concentrated sulphuric acid:—

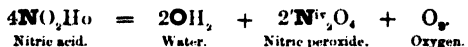


By employing two molecules of potassic nitrate and one of sulphuric acid a saving of sulphuric acid is effected, but a higher temperature is required, which destroys some of the nitric acid. The reaction takes place in two stages:—

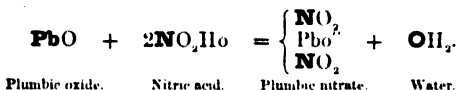
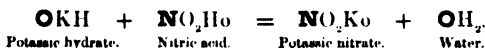




Decompositions.—1. The decomposition which nitric acid undergoes by heat is expressed in the following equation:—



2. By the action of metallic oxides or hydrates, nitric acid produces nitrates:—



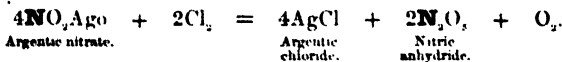
NITRIC ANHYDRIDE.



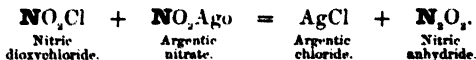
Probable molecular weight = 108. *Probable molecular volume* ⁶

 . *Fuses at* 29°·5. *Boils at* 45°.

Preparation.—1. By passing dry chlorine over argentic nitrate, heated first to 93° and then to 66°.



2. By passing the vapour of nitric dioxychloride over argentic nitrate heated to 60°–70°.



Reaction.—By the action of water it forms nitric acid:—



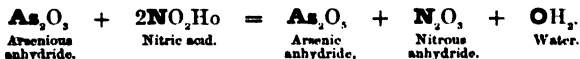
NITROUS ANHYDRIDE.



Probable molecular weight = 76. *Probable molecular volume*
 $\square\square$.

Preparation.—1. By heating together nitric acid and starch.

2. By gently heating nitric acid with arsenious anhydride :—



3. By the action of strong nitric acid on silver :—



NITROUS ACID.

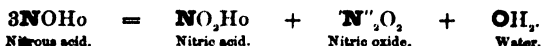


Molecular weight = 47.

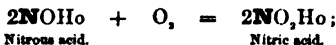
Preparation.—By mixing liquefied nitrous anhydride with a small quantity of water :—



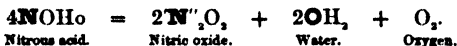
Decompositions.—1. In the presence of much water, nitric acid and nitric oxide are formed :—



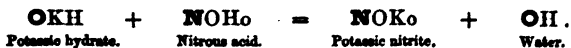
2. Nitrous acid acts as a reducing agent under some circumstances :—



and as an oxidizing agent under others :—



3. By the action of metallic oxides or hydrates, nitrous acid forms nitrites :—



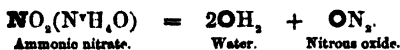
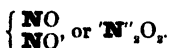
NITROUS OXIDE, Laughing Gas.

Molecular weight = 44. Molecular volume $\square\square$. *1 litre weighs 22 griths. Fuses at -101° . Boils at -88° .*

Preparation.—1. By the action of dilute nitric acid on zinc:—

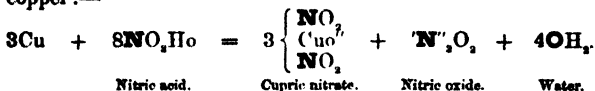


2. By heating ammonic nitrate:—

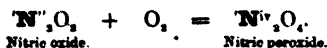
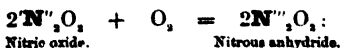
**NITRIC OXIDE.**

Molecular weight = 60. Molecular volume anomalous 1 litre weighs 15 griths.

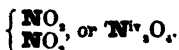
Preparation.—By the action of nitric acid upon mercury or copper:—



Reaction.—Unites directly with oxygen:—



NITRIC PEROXIDE.



Molecular weight = 92. *Molecular volume* $\square\square$ to $\square\square$. 1 litre weighs 23 to 46 criths. *Melts at* -9° . *Boils at* 22° .

Preparation.—1. By the union of nitric oxide with oxygen (see above).

2. By the action of nitric acid upon tin:—



Decomposition.—By the action of metallic hydrates and oxides it produces nitrites and nitrates:—



COMPOUNDS CONTAINING NITROGEN, CHLORINE, AND OXYGEN.

NITROUS OXYCHLORIDE, Chloronitrous Gas.



Molecular weight = 65.5. *Molecular volume* $\square\square$. 1 litre weighs 32.75 criths. *Boils at* 0° .

A mixture of nitric and hydrochloric acids possesses the property of dissolving gold, and is therefore called aqua regia; when heated it evolves chlorine and nitrous oxychloride:—

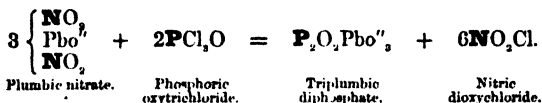


NITRIC DIOXY-TETRACHLORIDE, Chloronitric Gas.

Prepared, together with nitrous oxychloride, by heating a mixture of nitric and hydrochloric acids :—

**NITRIC DIOXYCHLORIDE, Chloropernitric Gas.**

Preparation.—By mixing phosphoric oxytrichloride and plumbic nitrate :—

**COMPOUNDS OF NITROGEN WITH HYDROGEN.****AMMONIA.**

Molecular weight = 17. *Molecular volume* $\square\square$. 1 litre weighs 8.5 criths. *Fuses at* -75° . *Boils at* $-38^\circ.5$.

Occurrence.—In the atmosphere and in rain water in very minute quantities.

Formation.—By the decay of animal and vegetable matters containing nitrogen.

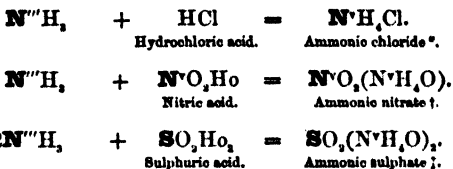
Manufacture.—By the destructive distillation of animal matter, as horn or bones, and of vegetable matter, as coal.

Preparation.—By heating a mixture of lime and ammoniac chloride (sal-ammoniac) :—



Reactions.—1. Decomposed by chlorine (see p. 62).

2. Unites directly with acids, forming the ammonium salts in which the atomicity of nitrogen is 3:—

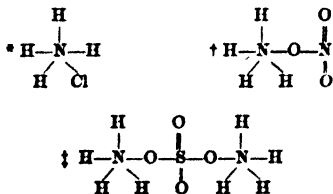


AMMONIUM.



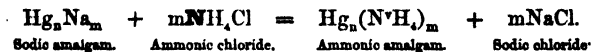
This monad radical has never been obtained in the free state ; but its compounds are perfectly analogous, in crystalline form and other properties, to those of potassium. These facts have induced some chemists to consider the group NH_4 as a metal, to which they have given the name ammonium—an hypothesis which is considered to receive support from the production of an unstable amalgam of this radical. All the compounds of mercury with metals are found to possess metallic lustre ; and this is also the case with the amalgam of ammonium. It may be prepared by two different processes.

1. If a solution of ammonio chloride be electrolyzed, the negative electrode being mercury and the positive a platinum



plate, the mercury is observed to swell up, owing to the formation of a spongy metallic mass.

2. By preparing an amalgam of potassium or of sodium, and pouring it into a slightly warmed solution of ammoniac chloride, the amalgam is found to swell enormously, potassic or sodic chloride being simultaneously formed:—



Ammoniac amalgam rapidly decomposes into mercury, ammonia, and hydrogen, the ammonia and hydrogen being liberated in the proportions of 2NH_3 to H_2 :—



Ammonium plays the part of a compound monad radical; and its salts are isomorphous with those of potassium; they are all volatile, unless the acid from which they are derived be fixed.

COMPOUND OF NITROGEN WITH CHLORINE.

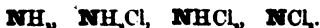
NITROUS CHLORIDE.



Preparation.—By the action of chlorine upon ammoniac chloride:—



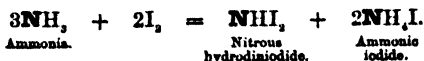
The formula of this compound is not fixed with certainty: it may contain hydrogen; and it is possible that the two compounds intermediate between ammonia and nitrous chloride may exist:—



COMPOUND OF NITROGEN WITH IODINE AND HYDROGEN.

NITROUS HYDRODINIODIDE.

Preparation.—By the action of ammonia on iodine a brown substance is obtained, which has the composition NHI_2 . It is formed according to the following equation:—



CHAPTER XIII.

HEXAD ELEMENTS.

SECTION I.

SULPHUR, S_2 .

Atomic weight = 32. *Molecular weight* = 64. *Molecular volume* $\square\square$ at 1000° , but only one-third of this at its boiling-point. 1 litre of sulphur vapour weighs 32 criths. *Rhombohedral variety* fuses at 114.5 and boils at 445° . *Atomicity* " iv and vi. *Evidence of atomicity*:—

Hydrosulphuric acid	$\text{S}''\text{H}_2$.
Triethylsulphine iodide	$\text{S}''\text{Et}_3\text{I}$.
Sulphuric dioxydichloride	$\text{S}''\text{O}_2\text{Cl}_2$.
Sodic nitrosulphate	$\text{S}''\text{O}(\text{NO})_2\text{NaO}_2$.

Occurrence.—Found in the free state in volcanic districts, and widely diffused in combination with metals and oxygen, as sulphides and sulphates.

Manufactured from native sulphur, and from

Iron pyrites	FeS''_2 .
Copper pyrites	$(\text{FeCu})\text{S}''_2$.
Calcic oxysulphide	$\text{Ca}_2\text{OS}''$.

Character.—Sulphur is capable of existing in several allotropic forms, of which the following are the most important:—

Condition.	Specific gravity.	Behaviour with carbonic disulphide.
α . Octahedral	2.05	Soluble.
β . Prismatic	1.98	Transformed into α .
γ . Plastic	1.95	Insoluble.
δ . Powder	1.95	Insoluble.

When united exclusively with positive elements or radicals, sulphur is almost invariably a dyad; and it is then the analogue of oxygen, as will be seen from the following formulæ:—

Oxygen compounds ... OK_2 , OKH , CO_2 , COKo_2 .
Sulphur compounds ... SK_2 , SKH , CS''_2 , $\text{CS}''\text{Ks}_2$.

COMPOUNDS OF SULPHUR WITH POSITIVE ELEMENTS.

Sulphuretted hydrogen SH_2 .
Hydrosulphyl $\text{'S'}_2\text{H}_2$, or Hs_2 .
Carbonic disulphide..... CS''_2 .

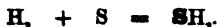
SULPHURETTED HYDROGEN, *Hydrosulphuric Acid*, *Sulphhydric Acid*.



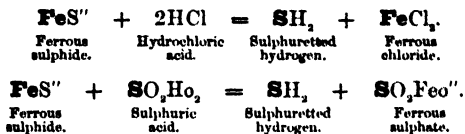
Molecular weight = 34. *Molecular volume* $\square\square$. 1 litre weighs 17 criths. Solid at $-85^\circ.5$. Liquid under a pressure of 17 atmospheres at 10° .

Occurrence.—Evolved with other gases from volcanoes and fumaroles. Found also in hepatic mineral waters, and frequently in waters which contain both organic matters and sulphates.

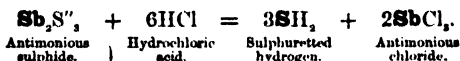
Preparation.—1. By direct union of its elements:—



2. By the action of hydrochloric or dilute sulphuric acid on ferrous sulphide:—



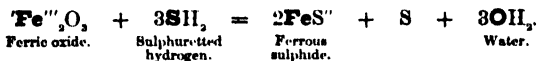
3. By the action of hydrochloric acid on antimonious sulphide with the aid of a gentle heat:—



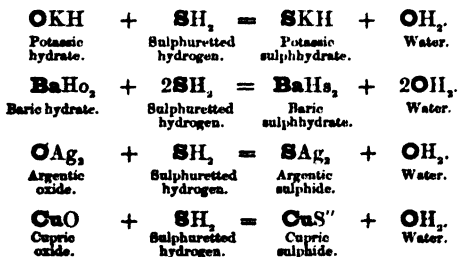
Reactions.—1. It is immediately decomposed by chlorine, thus:—



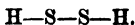
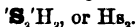
2. It is also rapidly decomposed by many metallic compounds rich in oxygen, such as ferric oxide:—



3. The sulphhydrates and sulphides of the metals are produced by the action of hydrosulphuric acid on the hydrates and oxides, thus:—

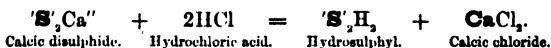


HYDROSULPHYL, Hydric Persulphide.



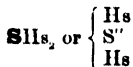
Probable molecular weight = 66. *Sp. gr.* 1.769.

Preparation.—By pouring a solution of calcic disulphide into hydrochloric acid:—



Character.—It is the analogue of hydroxyl in composition and functions.

HYPO-SULPHUROUS HYDROSULPHATE.



Probable molecular weight = 98.

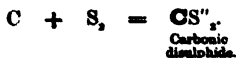
Preparation.—When a cold saturated solution of strychnine in alcohol is mixed with an alcoholic solution of yellow ammonic sulphide, a crystalline compound is formed containing $C_{21}H_{22}N_2O_8, H_2S_2$. By the action of sulphuric acid upon this compound, hyposulphurous hydrosulphate is liberated as a yellow oily body.

CARBONIC DISULPHIDE, Bisulphide of Carbon.

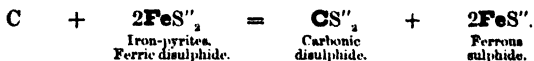


Molecular weight, = 76. *Molecular volume* $\square\square$. 1 litre of carbonic disulphide vapour weighs 38 criths. *Specific gravity of liquid* 1.293. *Boils at* 46° 6.

Preparation.—1. By passing sulphur over strongly ignited charcoal:—



2. By heating together charcoal and iron- or copper-pyrites :—

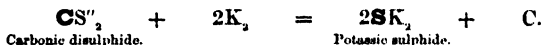


Iron-pyrites.
Ferric disulphide.

CS₂
Carbonic
disulphide.

2FeS".
Ferrous
sulphide.

Decompositions.—1. Heated potassium burns in the vapour of carbonic disulphide, with formation of potassic sulphide and liberation of carbon:—



Carbonic disulphide.

Potassic sulphide.

2. When brought into contact with a solution of an alkaline hydrate, carbonic disulphide is decomposed, a carbonate and a sulpho-carbonate being formed :—



Potassic hydrate.

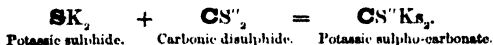
Carbonic disulphide.

Potassic
sulpho-carbonate.

Potassium carbonate.

Water.

3. In contact with solutions of alkaline sulphides, carbonic disulphide also forms alkaline sulpho-carbonates:—

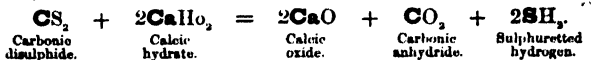


Potassic sulphide.

Carbonic disulphide.

Potassic sulpho-carbonate

4. When the vapour of carbonic disulphide is passed over heated calcic hydrate it is decomposed, carbonic anhydride and sulphuretted hydrogen being evolved :—



**Carbonio
disulphide.**

Calcic hydrate.

Calcic oxide.

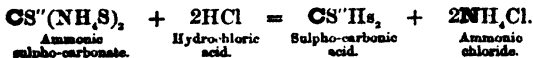
Carbonic anhydride.

Sulphuretted hydrogen.

SULPHO-CARBONIC ACID.



Preparation.—By the action of hydrochloric acid on ammoniac sulpho-carbonate :—



Ammonio sulpho-carbonate.

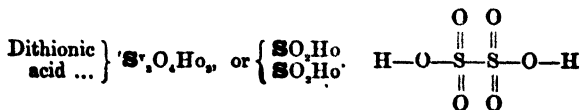
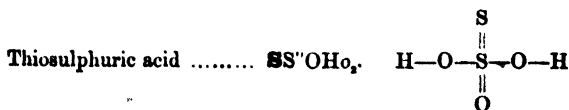
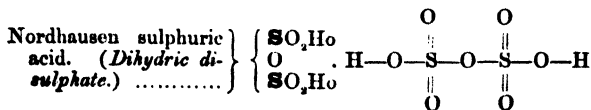
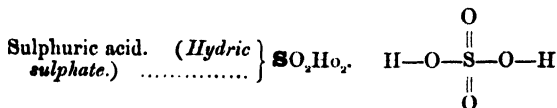
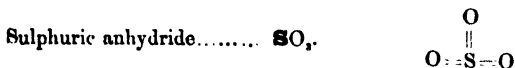
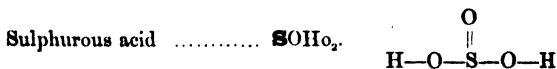
**Hydrochloric
acid.**

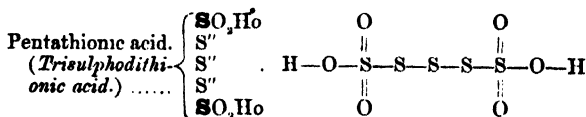
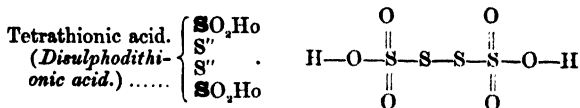
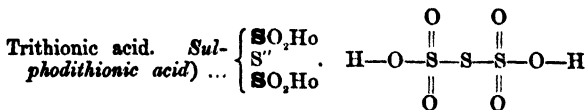
Sulpho-carbonic acid.

Ammoniochloride.

**COMPOUNDS OF SULPHUR WITH OXYGEN AND
HYDROXYL.**

In these compounds the sulphur is either a dyad, a tetrad, or a hexad.

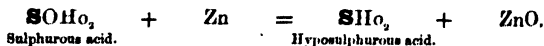




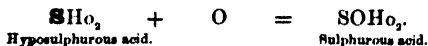
HYPOSULPHUROUS ACID.



Formation.—By the action of zinc upon aqueous sulphurous acid :—



Reaction.—Absorbs free oxygen with avidity, producing sulphurous acid :—



SULPHUROUS ANHYDRIDE.



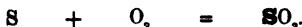
Molecular weight = 64. *Molecular volume* $\square\square$. 1 litre weighs 32 grs. Solid at -76° . Liquid under the pressure of two atmospheres at 7° . Boils at -8° .

Occurrence.—1. As a volcanic product.

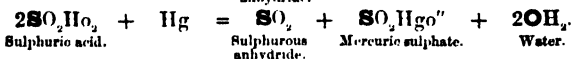
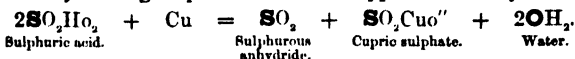
2. In the air of towns.

3. Evolved in the roasting of copper pyrites and other sulphureous ores.

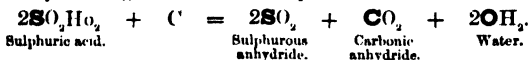
Preparation.—1. By the combustion of sulphur in air or in oxygen:—



2. By heating sulphuric acid with copper or mercury:—



3. By heating charcoal with sulphuric acid:—



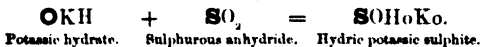
4. By heating a mixture of about three parts by weight of sulphur (two atoms) with four of manganic oxide (one molecule):—



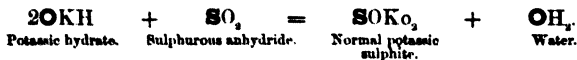
Reactions.—1. Dissolved by water, producing an acid liquid which, when cooled to 0° , deposits white cubical crystals of sulphurous acid:—



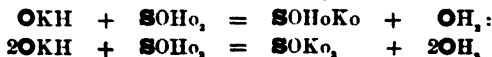
2. Sulphurous anhydride, when passed into solutions of the metallic hydrates, produces sulphites. If the sulphurous anhydride be in excess, an acid sulphite is obtained:—



3. If the metallic hydrate be in excess, a normal sulphite is formed, thus:—



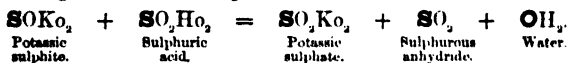
4. Sulphurous acid, when acted upon by metallic hydrates, produces the same salts:—



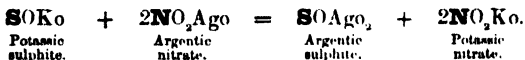
5. Sulphurous anhydride, when passed over metallic peroxides, produces sulphates :—



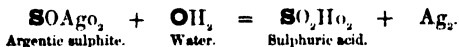
Detection.—Sulphites are recognized by the pungent odour of sulphurous anhydride which they evolve on the addition of a strong acid, such as sulphuric acid :—



When solutions of sulphites are mixed with solution of argentic nitrate, a white precipitate of argentic sulphite is formed :—



When this argentic sulphite is boiled with water, it becomes black, owing to the separation of metallic silver :—

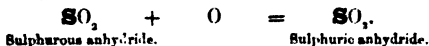


SULPHURIC ANHYDRIDE.



Molecular weight = 80. *Molecular volume* $\square\square$. 1 litre of sulphuric anhydride vapour weighs 40 criths. *Fuses at* $24^\circ.5$. *Boils at* $52^\circ.6$. *Sp. gr.* 1.95.

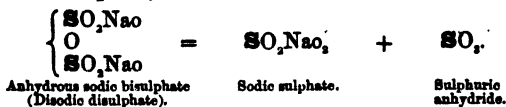
Preparation.—1. By passing a mixture of sulphurous anhydride and oxygen over ignited spongy platinum :—



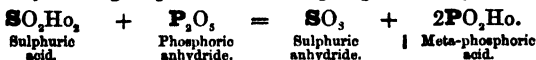
2. By heating Nordhausen sulphuric acid :—



3. By heating the so-called anhydrous sodic bisulphate (disodic disulphate) :—



4. By heating sulphuric acid with phosphoric anhydride :—



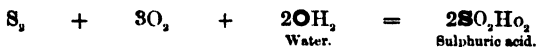
SULPHURIC ACID.



Molecular weight = 98. *Molecular volume* $\begin{array}{|c|c|} \hline & \\ \hline \end{array}$. *Dissociation.*

1 litre of sulphuric acid vapour weighs 24.5 criths. *Sp.* gr. 1.85. *Boils at* 325°.

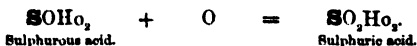
Preparation.—1. By the spontaneous oxidation of sulphur in the presence of water :—



2. By the action of hydroxyl upon sulphurous anhydride :—



3. By the exposure of a solution of sulphurous acid to air or oxygen :—

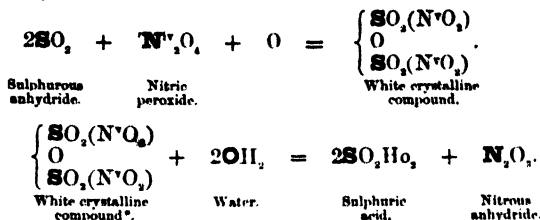


4. By the addition of water to sulphuric anhydride :—

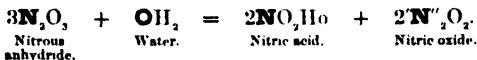


5. By the action of nitric peroxide and oxygen on sulphurous anhydride and subsequent decomposition by water of the white

crystalline compound thus produced (Brüning and De la Provostaye) :—



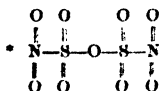
In the manufacture of sulphuric acid on the large scale, the nitrous anhydride is again acted on by water and transformed into nitric acid and nitric oxide :—



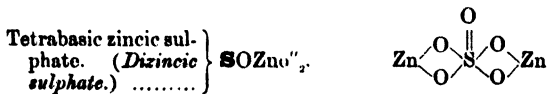
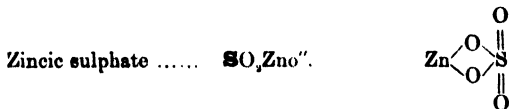
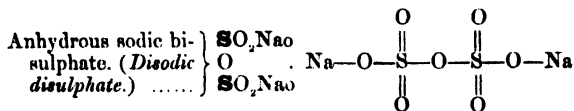
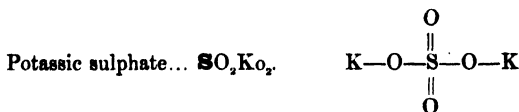
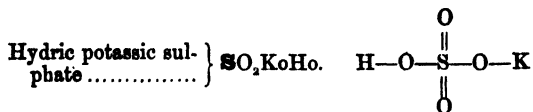
The nitric oxide, by the action of oxygen, reproduces nitric peroxide, which is then ready to undergo the same processes a second time. The nitric acid is at the same time reduced to nitric peroxide by the action of sulphurous anhydride :—

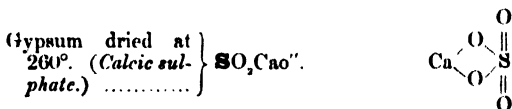
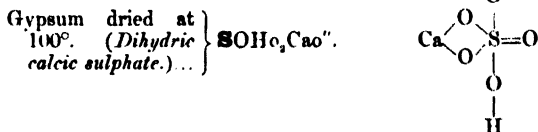
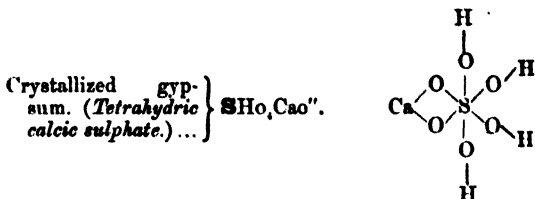


The crude sulphuric acid may be freed from traces of nitrous anhydride (which it always contains) by the addition of some ammoniac sulphate :—



Character.—Sulphuric acid forms several classes of salts:—

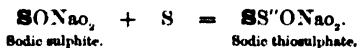




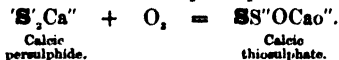
THIOSULPHURIC ACID, *Hyposulphurous Acid*.

$\text{SS}''\text{OHo}_2$ (hypothetical).

Preparation of Thiosulphates.—1. By boiling a solution of sodic sulphite with sulphur:—



2. By exposure of an alkaline persulphide to the air:—

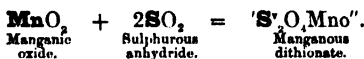


Reaction.—The thiosulphates, when acted upon by acids, evolve sulphurous anhydride, whilst sulphur is precipitated:—

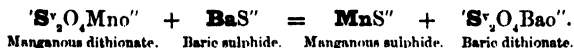


DITHIONIC ACID, Hyposulphuric Acid.

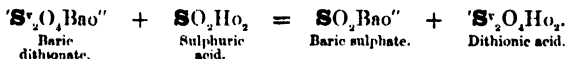
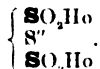
Preparation.—Powdered manganic oxide is suspended in water and a current of sulphurous anhydride passed through the liquid, when the manganic oxide gradually dissolves. The solution contains manganous dithionate or hyposulphate:—



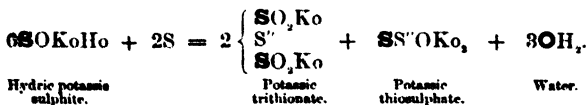
This solution is next treated with baric sulphide, which precipitates manganous sulphide; baric dithionate existing in the solution:—



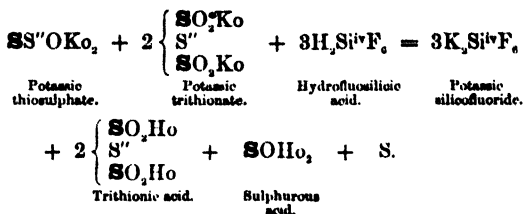
By adding sulphuric acid to a solution of the baric dithionate, baric sulphate is precipitated and dithionic acid remains in solution:—

**TRITHIONIC ACID, Sulphodithionic Acid.***Sulphureted Hyposulphuric Acid.*

Preparation.—By digesting hydric potassic sulphite with sulphur, potassic trithionate and potassic thiosulphate (*hyposulphite*) are formed:—



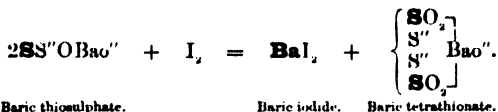
The two salts so produced, when decomposed by hydrofluosilicic acid, yield trithionic acid, sulphurous acid, and sulphur:—



**TETRATHIONIC ACID, Disulphodithionic Acid,
Bisulphuretted Hyposulphuric Acid.**

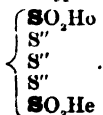


Preparation.—When iodine is added to baric thiosulphate (*hyposulphite*), baric iodide and baric tetrathionate are produced:—

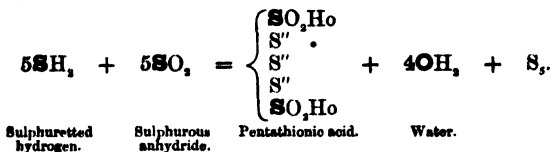


This salt, when decomposed by sulphuric acid, yields tetrathionic acid.

**PENTATHIONIC ACID, Trisulphodithionic Acid,
Trisulphuretted Hyposulphuric Acid.**



Preparation.—This acid is obtained by the action of hydro-sulphuric acid on sulphurous anhydride:—



SELENIUM, Se_2 .

Atomic weight = 79. *Molecular weight* = 158. *Molecular volume* $\square\square$. 1 litre of selenium vapour weighs 79 criths. *Sp. gr.* 4·3. *Fuses* a little above 100° . *Boils* at about 700° . *Atomicity* ", ^{iv}, and ^{vi}. *Evidence of atomicity*:—

Hydroselenic acid.....	$\text{Se}''\text{H}_2$.
Selenious chloride.....	$\text{Se}^{\text{iv}}\text{Cl}_4$.
Selenic acid	$\text{Se}^{\text{vi}}\text{O}_2\text{Ho}_2$.

Occurrence.—In small quantities in some mineral sulphides.

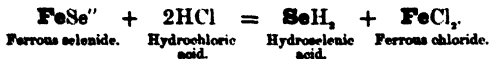
COMPOUNDS OF SELENIUM WITH HYDROGEN AND CHLORINE.

SELENIURETTED HYDROGEN, *Hydroselenic Acid*.



Molecular weight = 81. *Molecular volume* $\square\square$. 1 litre weighs 40·5 criths.

Preparation.—By the action of hydrochloric acid upon ferrous selenide:—



Character.—Like hydrosulphuric acid, it produces precipitates in solutions of most of the heavy metals.

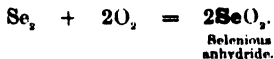
There are two chlorides of selenium: ' Se ',Cl and ' Se 'Cl₂.

**COMPOUNDS OF SELENIUM WITH OXYGEN
AND HYDROXYL.**

Selenious anhydride	SeO₂.
Selenious acid	SeOH₂.
Selenic acid	SeO₂Ho₂.

These bodies closely resemble the corresponding sulphur compounds.

Selenious anhydride is formed by burning selenium in oxygen:—



Selenious acid is formed by dissolving the anhydride in boiling water and crystallizing.

Potassic seleniate is prepared by fusing selenium or metallic selenides with nitre. The acid is obtained by transforming the potassic salt into a plumbic salt, and subsequently decomposing the latter with hydrosulphuric acid.

TELLURIUM, Te₂.

Atomic weight = 128. *Molecular weight* = 256. *Sp. gr.* 6·2.
Fuses at 490°–500°. *Atomicity* " , iv, and vi. *Evidence of atomicity* :—

Hydrotelluric acid.....	Te^{vi}H₂.
Tellurous chloride.....	Te^{iv}Cl₄.
Telluric acid	Te^{vi}O₂Ho₂.

This element is of even less importance than selenium, which it closely resembles.

The following compounds are known :—

Hydrotelluric acid (<i>telluretted hydrogen</i>)	TeH_2 .
Hypotellurous chloride	TeCl_2 .
Tellurous chloride	TeCl_4 .
Tellurous anhydride.....\.	TeO_2 .
Telluric anhydride	TeO_3 .
Tellurous acid	TeOH_2 ?
Telluric acid	TeO_3H_2 .

CHAPTER XIV.

MONAD ELEMENTS.

SECTION II. (*continued from Chap. VIII.*)

BROMINE, Br_2 .

Atomic weight = 80. *Molecular weight* = 160. *Molecular volume* $\square\square$. 1 litre of bromine vapour weighs 80 criths. *Sp. gr.* 3.18. *Fuses* at -20° . *Boils* at 63° . *Atomicity* '.
Evidence of Atomicity :—

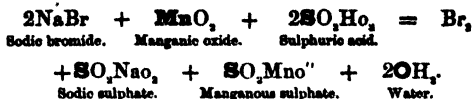
Hydrobromic acid	HBr .
Potassic bromide	KBr .
Argentie bromide	AgBr .

Occurrence.—In small quantities in some saline mineral waters. In sea-water, and the waters of the Dead Sea.

Preparation.—1. By the treatment with chlorine, of the mother-liquors of saline waters containing bromides, and extracting the liberated bromine by ether :—



2. By heating together sulphuric acid, sodic bromide, and manganic oxide:—



Character.—Bromine unites with several metals directly, and with great energy. Antimony and arsenic burn in it with brilliancy.

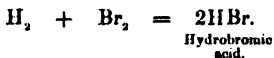
At 0° bromine combines with water, forming a crystalline compound, $\text{Br}_2 \cdot 10\text{OH}_2$.

HYDROBROMIC ACID.

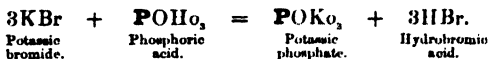


Molecular weight = 81. *Molecular volume* $\square\square$. 1 litre of hydrobromic acid weighs 40·5 criths. *Fuses at* -73° . *Boils at* -69° .

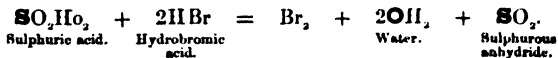
Preparation.—1. By passing a mixture of hydrogen and bromine vapour through a red-hot tube, or by burning hydrogen in a mixture of bromine vapour and air:—



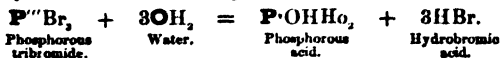
2. By heating potassic bromide with phosphoric acid:—



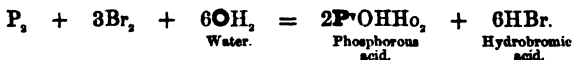
Sulphuric acid cannot be employed for this operation, as a portion of the hydrobromic acid is then decomposed, bromine being liberated:—



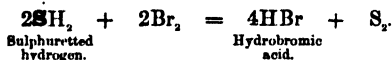
3. By the action of water upon phosphorous tribromide:—



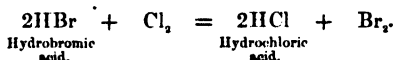
4. By gradually dropping bromine into water containing amorphous phosphorus :—



5. By passing sulphuretted hydrogen through water containing bromine :—



Reactions.—1. Decomposed by chlorine with liberation of bromine :—

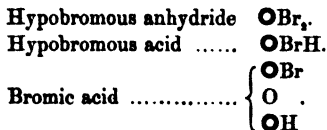


2. By the action of atmospheric oxygen a small quantity of bromine is liberated ; but the decomposition is soon arrested :—



3. In contact with metallic oxides, hydrates, and salts, bromides are formed.

COMPOUNDS OF BROMINE WITH OXYGEN AND HYDROXYL.



The graphic formulæ of these compounds are analogous to those of the corresponding chlorine compounds, given at page 46.

HYPOBROMOUS ANHYDRIDE.



Preparation.—By passing bromine vapour over dry mercuric oxide :—



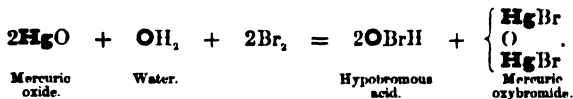
HYPOBROMOUS ACID.



Preparation.—1. By passing hypobromous anhydride into water :—



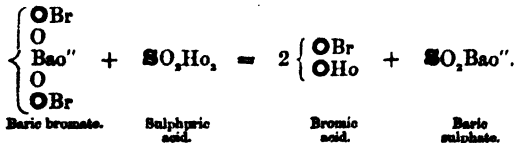
2. By agitating mercuric oxide with bromine-water :—



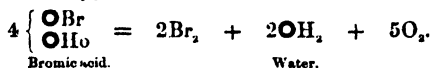
BROMIC ACID.



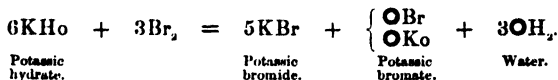
Preparation.—By acting upon a solution of baric bromate with sulphuric acid :—



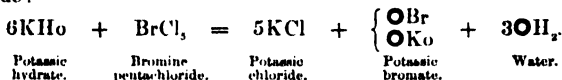
Reaction.—By boiling, bromic acid decomposes into water, bromine, and oxygen :—



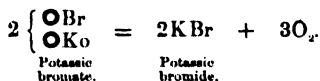
Preparation of bromates.—1. By adding bromine to a solution of a metallic hydrate, and separating the bromate by crystallization :—



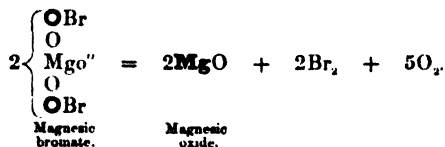
2. By the action of potassic hydrate on bromine pentachloride :—



Character of bromates.—Some of the bromates when heated lose oxygen, being transformed into bromides :—



Others evolve bromine and a portion of their oxygen, leaving metallic oxides :—



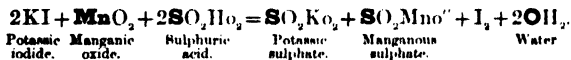
IODINE, I₂.

Atomic weight = 127. *Molecular weight* = 254. *Molecular volume* $\square\square$. 1 litre of iodine vapour weighs 127 criths. *Sp. gr.* 4.95. *Fuses* at 107°. *Boils* at 180°. *Atomicity* '.
Evidence of atomicity :—

Hydriodic acid.....	HI.
Potassic iodide.....	KI.
Argentie iodide	AgI.

Occurrence.—In mineral springs, in sea-water, and in considerable quantities in sea-plants.

Manufacture.—Sea-weeds are burnt or carbonized in iron retorts, and the ash or charcoal is extracted with water. The liquid is evaporated, and, after a considerable quantity of sodic carbonate and chloride has crystallized out, the mother-liquor, which contains potassic iodide, is distilled with sulphuric acid and manganic oxide:—



Reactions.—1. Iodine is separated from nearly all its compounds by chlorine and bromine:—



2. Iodine unites directly with many metals.

HYDRIODIC ACID.

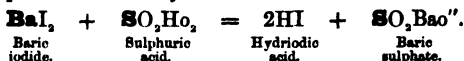
HI.

Molecular weight = 128. *Molecular volume* $\square\square$. 1 litre of hydriodic acid weighs 64 criths. *Fuses at* -55° .

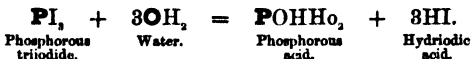
Preparation.—1. By passing iodine vapour and hydrogen through a red-hot tube or over spongy platinum gently heated:—



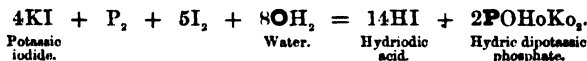
2. By the action of dilute sulphuric acid on baric iodide, or of phosphoric acid on any iodide :—



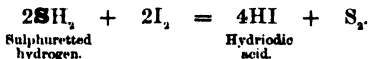
3. By decomposing phosphorous triiodide by water :—



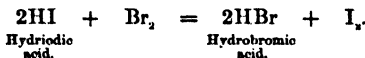
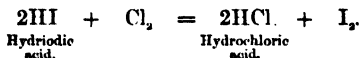
4. By heating together water, potassic iodide, iodine, and phosphorus :—



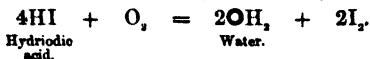
5. A solution of hydriodic acid is obtained by passing sulphuretted hydrogen through water in which iodine is suspended :—



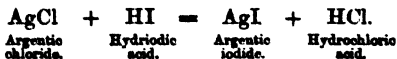
Reactions.—1. Decomposed by chlorine and bromine, with liberation of iodine :—



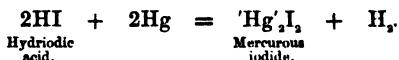
2. It is gradually but completely decomposed by atmospheric oxygen ; the iodone, which at first remains dissolved in the hydriodic acid, is after a time deposited in crystals :—



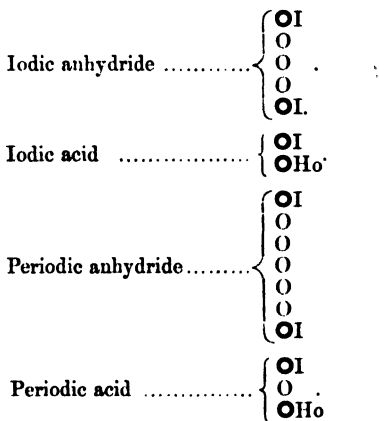
3. With metallic oxides, hydrates, and some salts it forms iodides. Even argentic chloride is transformed by hydriodic acid into argentic iodide :—



4. Hydriodic acid is rapidly decomposed by mercury, with liberation of hydrogen :—

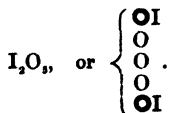


COMPOUNDS OF IODINE WITH OXYGEN AND HYDROXYL.

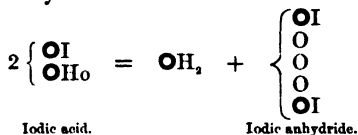


The graphic formulæ of these compounds are analogous to those of the corresponding chlorine compounds given at p. 46.

(IODIC ANHYDRIDE.



Preparation.—By heating iodic acid to 170° , when it separates into iodic anhydride and water:—

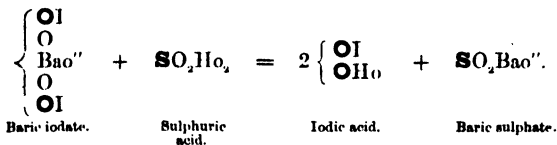


Reaction.—When strongly heated, it decomposes into iodine and oxygen.

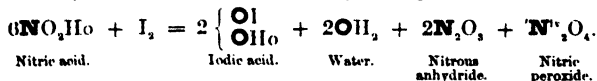
1. IODIC ACID.



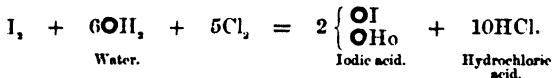
Preparation.—1. By the action of sulphuric acid upon baric iodate:—



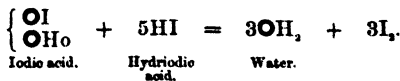
2. By oxidizing iodine with strong boiling nitric acid:—



3. By acting upon iodine and water with chlorine:—

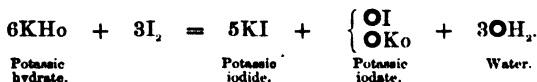


Reactions.—1. In contact with hydriodic acid it forms water and iodine:—

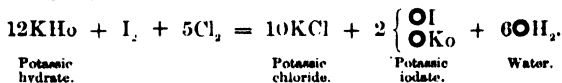


2. It is reduced by many other deoxidizing agents.

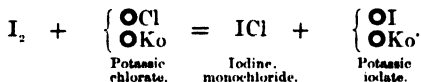
Preparation of Iodates.—1. By treating solutions of metallic hydrates with iodine, and separating the iodate by crystallization :—



2. By dissolving iodine in potassic hydrate and treating the mixture with chlorine :—



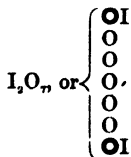
3. By heating together potassic chlorate and iodine :—



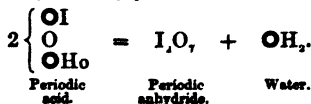
Character of Iodates.—Some of the iodates when heated split into iodides and oxygen, others into metallic oxides, iodine, and oxygen.

Iodic acid gives several well-defined anhydro-salts.

PERIODIC ANHYDRIDE.



Preparation.—By heating periodic acid to 160° :—

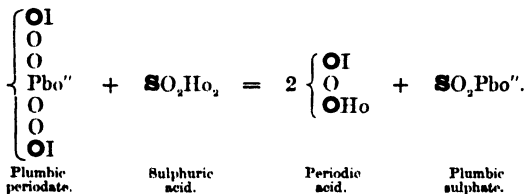


Reaction.—When heated it is decomposed into oxygen and iodic anhydride, and ultimately into iodine and oxygen.

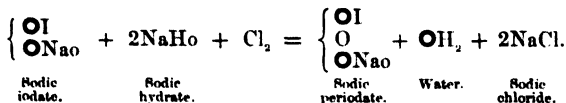
PERIODIC ACID.



Preparation.—By decomposing plumbic periodate with sulphuric acid:—



Preparation of Periodates.—Sodic periodate may be prepared by passing chlorine through mixed solutions of sodic hydrate and sodic iodate:—



FLUORINE, F₂.

Atomic weight = 19. *Molecular weight* = 38 (?). *Molecular volume* $\square\square$. 1 litre weighs 19 criths (?). *Atomicity* '.

Evidence of atomicity:—

Hydrofluoric acid..... HF.

Occurrence.—In combination with metals in fluorspar, cryolite, apatite, and other minerals. Widely but sparsely diffused. Little is known of fluorine in the uncombined condition.

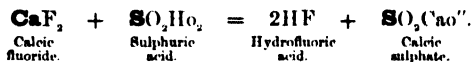
COMPOUND OF FLUORINE WITH HYDROGEN.

HYDROFLUORIC ACID.

HF.

Molecular weight = 20. *Molecular volume* $\square\square$. 1 litre weighs 10 criths. Boils at $-19^{\circ}5$. *Sp. gr. of liquid* .9875 at 13° .

Preparation.—By heating calcic fluoride with sulphuric acid in a leaden or platinum vessel:—



CHAPTER XV.

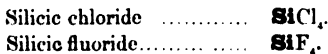
TETRAD ELEMENTS.

SECTION I. (Continued from Chapter XI.)

SILICON, *Silicium*, Si.

Atomic weight = 28.5. *Sp. gr. (graphitoidal)* = 2.49. *Atomicity* ¹.

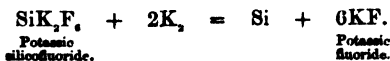
Evidence of atomicity:—



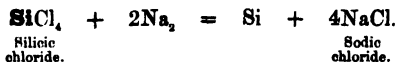
Occurrence.—Silicon is one of the most widely diffused elements. It is found, in combination with oxygen and metals, in a very large number of minerals.

a. Amorphous Silicon.

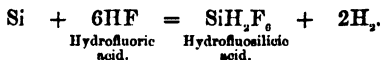
Preparation.—1. By heating potassic silicofluoride with potassium:—



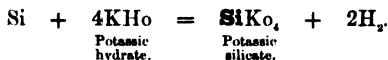
2. By heating sodium in a current of the vapour of silicic chloride :—



Reactions.—1. Silicon is dissolved by aqueous hydrofluoric acid, and converted into hydrofluosilicic acid :—



2. When fused with potassic hydrate, or boiled in its solution, it yields potassic silicate :—



3. Heated in the air, it burns, producing silicic anhydride.

β. Graphitoidal Silicon.

Preparation.—By fusing amorphous silicon with aluminium, and boiling the compound in hydrochloric or hydrofluoric acid, which dissolves the aluminium, leaving the silicon in the form of hexagonal plates with a metallic lustre.

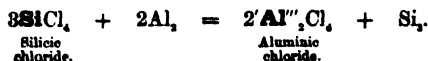
Character.—May be heated to whiteness in oxygen without burning.

Is gradually oxidized by a mixture of nitric and hydrofluoric acids.

Is slowly attacked by fused potassic hydrate.

γ. Adamantine Silicon.

Preparation.—1. By heating aluminium very strongly in a current of the vapour of silicic chloride. The aluminic chloride which is formed volatilizes, leaving the adamantine silicon behind :—



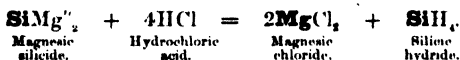
2. By fusing amorphous silicon.

SILICIC HYDRIDE.

Molecular weight = 32.5.

Preparation.—1. By decomposing dilute sulphuric acid by a feeble electric current passing from electrodes of aluminium containing silicon, when the silicic hydride is evolved at the negative pole.

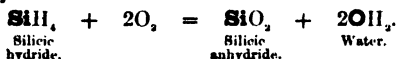
2. By decomposing magnesian silicide with hydrochloric acid :—



3. Both the above processes furnish silicic hydride mixed with much hydrogen ; but if ethylic silicoformate be placed in contact with sodium, it splits up into ethylic silicate and pure silicic hydride, the sodium remaining unaffected :—



Reactions.—1. Under reduced pressure or mixed with hydrogen, inflames spontaneously in air, producing water and silicic anhydride :—



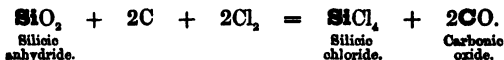
2. Decomposed by solution of potassic hydrate, yielding exactly four times its volume of hydrogen :—

**SILICIC CHLORIDE.**

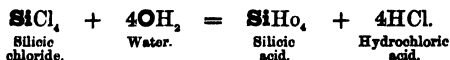
Molecular weight = 170.5. *Molecular volume* $\square\square$. 1 litre weighs 85.25 criths. *Sp. gr. of liquid* 1.52. *Boils at* 59°.

Preparation.—1. By burning silicon in chlorine.

2. By heating a mixture of carbon and silicic anhydride in a stream of chlorine:—



Reaction.—By contact with water it produces silicic and hydrochloric acids:—

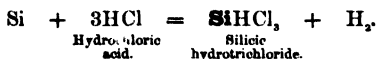


SILICIC HYDROTRICHLORIDE, *Silicon Chloroform.*

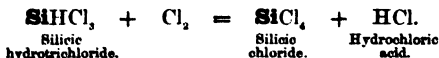


Molecular weight = 136. *Molecular volume* $\square\square$. 1 litre weighs 68 criths. *Boils at* 36°.

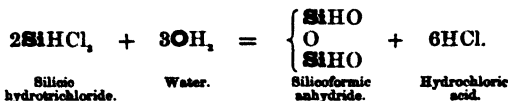
Preparation.—By heating crystallized silicon to dull redness in a current of hydrochloric acid gas:—



Reactions.—1. Is decomposed by chlorine at ordinary temperatures:—



2. By contact with water it is transformed into *Disilicic hydrotrioxide*, or *Silicoformic anhydride*:—



SILICIC BROMIDE.

Molecular weight = 348·5. *Sp. gr.* 2·813 at 0°. *Boils at* 153°.

Preparation.—By the same method as that employed for making the chloride, bromine vapour being substituted for chlorine.

Reaction.—Decomposed by water in the same manner as the chloride.

SILICIC IODIDE.

Molecular weight = 536·5. *Molecular volume* $\square\square$. *Fuses at* 120°·5. *Boils in carbonic anhydride at* 290°.

Preparation.—By passing iodine vapour and carbonic anhydride over red-hot silicon.

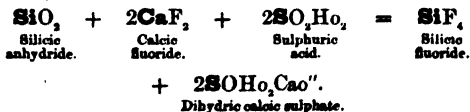
Reactions.—1. Decomposed by water into silicic and hydriodic acids.

2. By absolute alcohol it is decomposed, with production of silicic anhydride, ethylic iodide, and hydriodic acid :—

**SILICIC FLUORIDE.**

Molecular weight = 104·5. *Molecular volume* $\square\square$. 1 litre weighs 52·25 criths. *Fuses at* -140° C. *Condensable gas.*

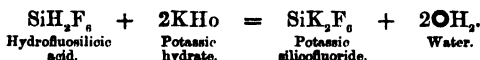
Preparation.—By heating together silicic anhydride, calcic fluoride, and sulphuric acid :—



Reaction.—By contact with water it produces silicic and hydrofluosilicic acids :—



By contact with metallic oxides, hydrates, and salts, hydrofluosilicic acid produces silicofluorides, some of which, as the potassic and baric compounds, are insoluble in water :—



COMPOUNDS OF SILICON WITH OXYGEN AND HYDROXYL.

Silicic anhydride SiO_2 .
Silicic acid SiH_2O_2 and SiOH_2 .

Other Modifications of Silicic acid.



SILICIC ANHYDRIDE.



Molecular weight = 60.5. *Sp. gr.* 2.65.

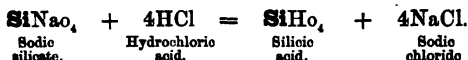
Occurrence.—In the pure state in many minerals, as quartz, agate, &c.

Preparation.—By heating silicic acid to 100° .

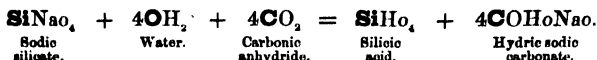
SILICIC ACID.

Tetrabasic... SiH_4O_4 . Dibasic... SiOH_2O_2 .

Preparation.—1. By treating a solution of a soluble silicate with hydrochloric acid:—



2. By passing a stream of carbonic anhydride through a solution of a soluble silicate:—



A reaction similar to this is the cause of the disintegration of granitic rocks.

3. By passing silicic fluoride through water. (See p. 104.)

4. The bibasic silicic acid is said to be produced by the evaporation *in vacuo* at 16° of a solution of the tetrabasic acid in water.

The acid prepared by the first three of the above processes has probably the formula SiH_4O_4 ; by drying in the air, a compound remains containing



This last acid, heated to 100° , loses more water, being transformed into



5. By the action of water on tetrethylic silicate, a compound is produced containing



SILICATES.

The soluble alkaline silicates may be prepared by fusing silicic anhydride, in the form of sand or flints, or insoluble natural silicates, with alkaline hydrates or carbonates.

The silicates form a very important class of minerals. The following list contains a few examples:—

Sand.	}	<i>Silicic anhydride.</i>	SiO₂.
Flint.			
Rock crystal.			
Quartz.			
Opal.			
Chalcedony.			
Peridote		<i>Dimagnesian silicate</i>	SiMgo''₂.
Phenacite.		<i>Digluccinic silicate</i>	SiGlo''₂.
Willemite.		<i>Dizincic silicate</i>	SiZno''₂.
Zircon.		<i>Zirconic silicate</i>	SiZro^{iv}.
Enstatite.		<i>Monomagnesian silicate</i> ...	SiOMgo''.
Yorke's Sodid silicate	{	SiNa_o,	.
		O	
		SiNa_o,	
Ophite (Noble Serpentine)	{	Si	Mgo''.
		O	
		Si	
Diopside.		<i>Calcic magnesian disilicate</i> ...	SiO SiO Cao''Mgo''.
Talc.		<i>Tetramagnesian pentasilicate</i>	Si₅O₈Mgo''₄.
Okenite.	{	SiHo₂	Cao''.
		O	
		SiHo₂	

Serpentine. <i>Dihydric trimagnesian disilicate</i>	$\left\{ \begin{array}{l} \text{SiHoMgo}'' \\ \text{Mgo}'' \\ \text{SiHoMgo}'' \end{array} \right.$
Steatite. <i>Trimagnesian tetrasilicate</i>	$\text{Si}_4\text{O}_8\text{Mgo}''.$
Meerschaum. <i>Tetrahydric dimagnesian trisilicate</i>	$\left\{ \begin{array}{l} \text{SiHoMgo}'' \\ \text{O} \\ \text{SiHo}_2 \\ \text{O} \\ \text{SiHoMgo}'' \end{array} \right.$
Pyrophyllite. <i>Dihydric aluminic tetrasilicate</i>	$\left. \begin{array}{l} \text{SiOHo} \\ \text{SiO} \\ \text{SiO} \\ \text{SiOHo} \end{array} \right\} \text{Alo}^{\text{vi}}.$
Anorthite. <i>Aluminic calcic disilicate</i> ...	$\text{Si}_2(\text{'Al'}''; \text{O}_6)^{\text{vi}}\text{Cao}''.$
Labradorite. <i>Aluminic calcic trisilicate</i>	$\left. \begin{array}{l} \text{SiO} \\ \text{SiCao}'' \\ \text{SiO} \end{array} \right\} \text{Alo}^{\text{vi}}.$
Grossularia. <i>Aluminic tricalcic trisilicate</i>	$\left. \begin{array}{l} \text{SiCao}'' \\ \text{SiCao}'' \\ \text{SiCao}'' \end{array} \right\} \text{Alo}^{\text{vi}}.$
Emerald. <i>Trigluconic aluminic hexasilicate</i>	$\left\{ \text{Si}_6\text{O}_{18}\text{Alo}^{\text{vi}}\text{Glo}'' \right\}.$
Chloropal. <i>Ferric trisilicate</i>	$\left. \begin{array}{l} \text{SiO} \\ \text{SiO} \\ \text{SiO} \end{array} \right\} \text{Feo}^{\text{vi}}, 3\text{OH}_2,$
Felspar. Orthose. <i>Dipotassic aluminic hexasilicate</i>	$\left\{ \text{Si}_6\text{O}_{18}\text{Ko}_2\text{Alo}^{\text{vi}} \right\}.$

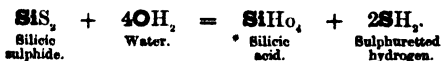
SILICIC SULPHIDE.



Preparation.—By passing the vapour of carbonic disulphide over silicic anhydride heated to redness :—



Reaction.—By the action of water, hydrosulphuric acid is evolved, and the solution contains silicic acid:—



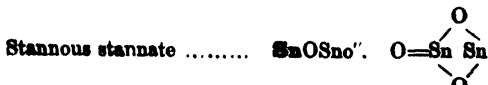
TIN, Sn.

Atomic weight = 118. *Molecular weight unknown.* *Sp. gr.* 7.28. *Fuses at 228°.* *Atomicity* " and iv, also a pseudo-triad.

The following are the names and probable formulæ of the principal compounds of this metal:—

Stannous chloride	SnCl₂.	
Stannic chloride	SnCl₄.	
Stannous oxide.....	SnO.	
Stannic oxide or anhydride	SnO₂.	
Distannous oxydichloride..	$\left\{ \begin{array}{l} \text{SnCl} \\ \text{O} \\ \text{SnCl} \end{array} \right.$	Cl—Sn—O—Sn—Cl
Stannous hydrate.....	SnHo₂.	H—O—Sn—O—H
Stannic acid	SnOHo₂.	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H—O—Sn—O—H} \end{array}$
Dipotassic stannite	SnKo₂.	
Dipotassic stannate	SnOKo₂, 4OH₂.	
Distannic trioxide	$\left\{ \begin{array}{l} \text{SnO} \\ \text{O} \\ \text{SnO} \end{array} \right.$	$\begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{O=Sn—Sn=O} \end{array}$

or



Metastannic acid (dried at 100°).....	$\left\{ \begin{array}{l} \text{SnHo}_3 \\ \text{O} \\ \text{SnHo}_3 \\ \text{O} \\ \text{SnO} \\ \text{O} \\ \text{SnHo}_3 \\ \text{O} \\ \text{SnHo}_3 \end{array} \right.$	
Dipotassic metastannate....	$\left\{ \begin{array}{l} \text{SnHo}_2\text{Ko} \\ \text{O} \\ \text{SnHo}_2 \\ \text{O} \\ \text{SnO} \\ \text{O} \\ \text{SnHo}_2 \\ \text{O} \\ \text{SnHo}_2\text{Ko} \end{array} \right.$	
Stannous sulphide.....	SnS'' .	
Stannic sulphide	SnS''_2 .	
Distannic trisulphide	$\left\{ \begin{array}{l} \text{SnS}''\text{S}'' \\ \text{SnS}''\text{S}'' \end{array} \right.$	$\begin{array}{c} \text{S} \\ \diagup \quad \diagdown \\ \text{S}=\text{Sn}-\text{Sn}=\text{S} \end{array}$
or		
Stannous sulphostannate...	SnSSns'' .	$\begin{array}{c} \text{S} \\ \diagup \quad \diagdown \\ \text{S}=\text{Sn} \quad \text{Sn} \\ \diagdown \quad \diagup \\ \text{S} \end{array}$
Stannous sulphate	$\text{SO}_2\text{Sno}''$.	$\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \diagdown \quad \diagup \\ \text{S} \quad \text{O} \quad \text{Sn} \\ \diagup \quad \diagdown \quad \parallel \\ \text{O} \quad \text{O} \end{array}$

TITANIUM, Ti.

Atomic weight = 50. *Molecular weight* unknown. *Sp. gr.* 5·3.

Atomicity " and iv, also a pseudo-triad.

The following are the names and probable formulæ of the chief compounds of titanium:—

Titanic tetrachloride	TiCl_4	$\begin{array}{c} \text{Cl} \\ \\ \text{Cl}-\text{Ti}-\text{Cl} \\ \\ \text{Cl} \end{array}$
Dititanic hexachloride ...	$\left\{ \begin{array}{l} \text{TiCl}_3 \\ \text{TiCl}_3 \end{array} \right.$	$\begin{array}{c} \text{Cl} \quad \text{Cl} \\ \quad \\ \text{Cl}-\text{Ti}-\text{Ti}-\text{Cl} \\ \quad \\ \text{Cl} \quad \text{Cl} \end{array}$
Titanous oxide.....	TiO	$\text{Ti}=\text{O}$
Titanic oxide or anhydride (Rutile, Anatase, Brook- ite)	$\left\{ \begin{array}{l} \text{TiO}_2 \\ \text{TiO}_2 \end{array} \right.$	
Titanic acid	TiOH_2	$\begin{array}{c} \text{O} \\ \\ \text{H}-\text{O}-\text{Ti}-\text{O}-\text{H} \end{array}$
Titanic sulphide	TiS_2	
Dititanic dinitride	$\left\{ \begin{array}{l} \text{TiN}'' \\ \text{TiN}''' \end{array} \right.$	$\text{N}\equiv\text{Ti}-\text{Ti}\equiv\text{N}$
Trititanic tetranitride.....	$\text{Ti}_3\text{N}'''$	$\begin{array}{c} \text{N} \\ / \quad \quad \backslash \\ \text{N}\equiv\text{Ti} \quad \text{Ti} \quad \text{Ti}\equiv\text{N} \\ \\ \text{N} \end{array}$

CHAPTER XVI.

PENTAD ELEMENTS.

SECTION I. (Continued from Chapter XII.)

PHOSPHORUS, P_4 .

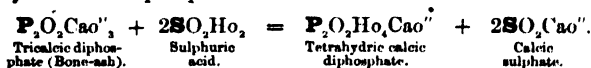
Atomic weight = 31. *Molecular weight* = 124. *Molecular volume* $\square\square$. 1 litre of phosphorus vapour weighs 62 criths. *Sp. gr.* 1.83. *Fuses at* 44–45°. *Boils at* 280°. *Atomicity* "" and *. *Evidence of atomicity* :—

Phosphorous trihydride.....	$P'''H_3$.
Phosphorous trichloride	$P'''Cl_3$.
Phosphoric chloride	$P'Cl_5$.
Phosphonic iodide	$P'H_4I$.

Occurrence.—In combination as a constituent of several minerals, and in small quantities in most rocks and soils.

In plants, and in the brain, nerves, urine, and bones of animals.

Manufacture.—Calcined bones or Sombrierite, both of which consist chiefly of calcic phosphate, are digested with sulphuric acid, by which the tricalcic diphosphate is converted into tetrahydric calcic diphosphate :—



The tetrahydric calcic phosphate is extracted with water from the calcic sulphate, evaporated, mixed with charcoal, dried and distilled, when phosphorus, carbonic oxide, and tricalcic diphosphate are produced :—



AMORPHOUS PHOSPHORUS. *Allotropic Phosphorus. Red Phosphorus.*

Obtained by heating common phosphorus to 230°–250° in close vessels.

Neither the number nor the arrangement of the atoms in the molecule of this variety of phosphorus is known.

COMPOUNDS OF PHOSPHORUS WITH HYDROGEN.

Phosphorus forms three compounds with hydrogen. They cannot be obtained by the direct combination of their elements.

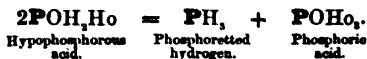
Solid phosphoretted hydrogen ...	$\left\{ \begin{array}{l} \text{P(P'''H)''} \\ \text{P(P'''H)''} \end{array} \right. ?$
Liquid ditto	$\text{P''}_2\text{H}_4$
Gaseous ditto	PH_3

GASEOUS PHOSPHORETTED HYDROGEN.



Molecular weight = 34. *Molecular volume* $\square\square$. *1 litre weighs* 17 criths.

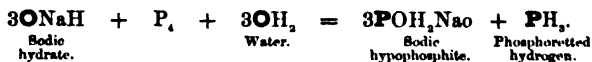
Preparation.—1. By heating hypophosphorous acid :—



2. By heating phosphorous acid :—

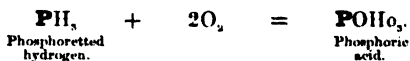


3. By heating phosphorus with solution of sodic or potassic drate :—

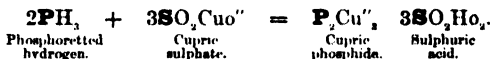


The gas prepared by this process contains free hydrogen and the vapour of liquid-phosphoretted hydrogen.

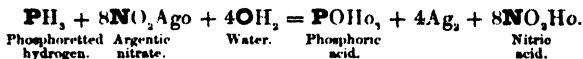
Reactions.—1. By combustion in oxygen it yields phosphoric acid :—



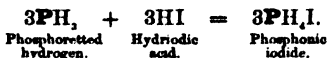
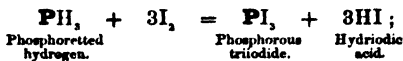
2. When passed through a solution of cupric sulphate, it causes a black precipitate of cupric phosphide :—



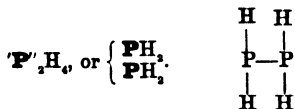
3. When passed through a solution of argentic nitrate, metallic silver and nitric and phosphoric acids are formed :—



4. It unites directly with hydriodic and hydrobromic acids when they are presented to it in the nascent state, forming compounds isomorphous with the corresponding substances in the nitrogen series :—

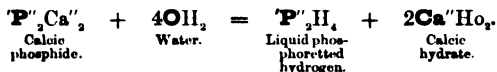


In this behaviour phosphoretted hydrogen bears a striking analogy to ammonia, although, unlike the latter compound, it does not unite with other acids.

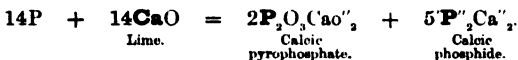
LIQUID PHOSPHORETTED HYDROGEN.

Molecular weight = 66. *Boils between* 30° and 40°.

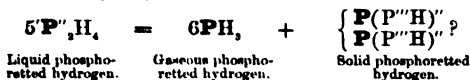
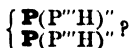
Preparation.—By the action of water or very dilute hydrochloric acid upon calcic phosphide, $'P''_2Ca''_2$, the gas evolved being transmitted through a freezing-mixture:—



The calcic phosphide is prepared by passing the vapour of phosphorus over lime heated to redness:—



Reaction.—Decomposed by sunlight into solid and gaseous phosphoretted hydrogen:—

**SOLID PHOSPHORETTED HYDROGEN.**

Molecular weight = 126 ?

Preparation.—By dissolving calcic phosphide in concentrated hydrochloric acid, or by the action of light upon the liquid phosphoretted hydrogen.

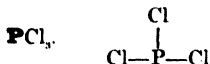
COMPOUNDS OF PHOSPHORUS WITH CHLORINE.

Phosphorus forms two compounds with chlorine:—

Phosphorous trichloride PCl_3 .

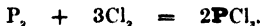
Phosphoric chloride PCl_5 .

PHOSPHOROUS CHLORIDE.

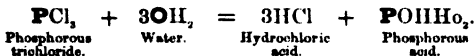


Molecular weight = 137·5. *Molecular volume* . 1 litre of phosphorous trichloride vapour weighs 68·75 criths. *Sp. gr.* 1·45. *Boils at* 74°.

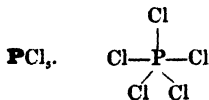
Preparation.—By the action of chlorine upon phosphorus:—



Reaction.—By the action of water it yields hydrochloric and phosphorous acids:—



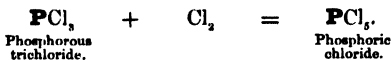
PHOSPHORIC CHLORIDE.



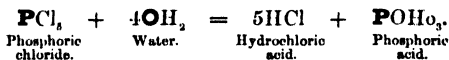
Molecular weight = 208·5. *Molecular volume* $\square\square$ to $\square\square$.

1 litre of phosphoric chloride weighs 52.1 to 104.25 criths.
Volatilizes below 100°.

Preparation.—By the action of chlorine upon phosphorous trichloride :—



Reactions.—1. By the action of an excess of water it produces hydrochloric acid and phosphoric acid :—

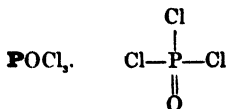


2. When submitted to the action of alcohols and acids, the chlorides of the radicals of the alcohols and acids are obtained, thus :—



COMPOUND OF PHOSPHORUS WITH CHLORINE AND OXYGEN.

PHOSPHORIC OXYTRICHLORIDE.



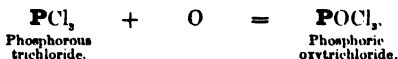
Molecular weight = 158.5. *Molecular volume* $\square\square$. 1 litre of

phosphoric oxytrichloride vapour weighs 76.75 criths. Sp. gr. 1.7. Boiling-point 110°.

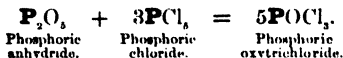
Preparation—1. By the action of a limited quantity of water on phosphoric chloride:—



2. By passing oxygen through boiling phosphorous trichloride:—

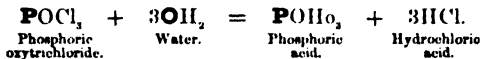


3. By heating phosphoric chloride with phosphoric anhydride:—

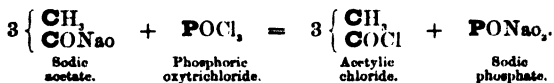


4. It is formed as a secondary product in the preparation of the chlorides of alcohol and acid radicals as above described (p. 116).

Reactions.—1. By contact with water it is transformed into hydrochloric and phosphoric acids:—



2. By distillation with the salts of organic acids it yields the chloracids:—



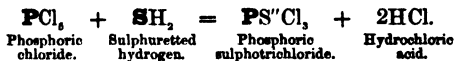
COMPOUND OF PHOSPHORUS WITH CHLORINE AND SULPHUR.

PHOSPHORIC SULPHOTRICHLORIDE.

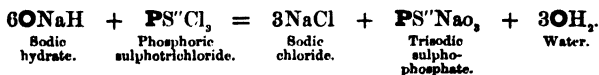


Molecular weight = 169.5. *Boils at* 128°.

Preparation.—By the action of sulphuretted hydrogen upon phosphoric chloride:—

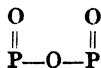


Reaction.—When boiled with sodic hydrate, it yields sodic chloride and trisodic sulphophosphate:—

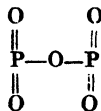


COMPOUNDS OF PHOSPHORUS WITH OXYGEN AND HYDROXYL.

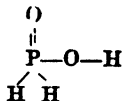
Phosphorous anhydride ... P_2O_3 .



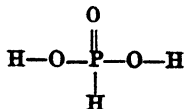
Phosphoric anhydride..... P_2O_5 .

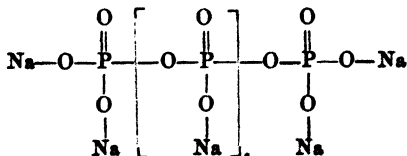
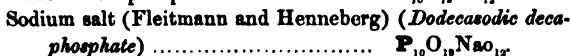
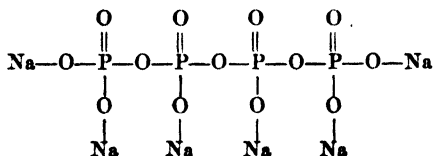
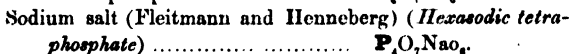
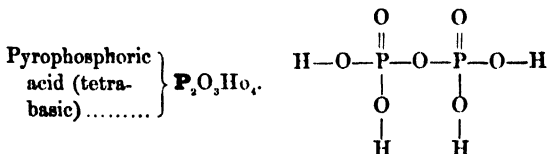
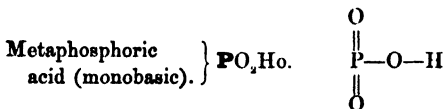
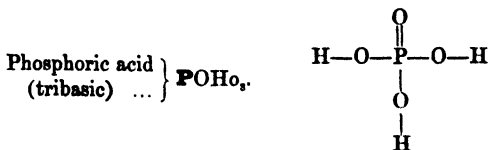


Hypophosphorous acid ... POH_2Ho .



Phosphorous acid..... POHHO_2 .





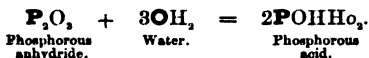
PHOSPHOROUS ANHYDRIDE.



Molecular weight = 110.

Preparation.—By the slow oxidation of phosphorus in a gentle current of dry air.

Reaction.—In contact with water it produces phosphorous acid :—



PHOSPHOROUS ACID.



Molecular weight = 82.

Preparation.—1. By the action of water on phosphorous anhydride as above.

2. By the slow oxidation of phosphorus in moist air.

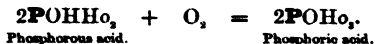
3. By the action of water upon phosphorous chloride (see p. 115).

4. By passing chlorine through phosphorus under hot water.

Reactions.—1. When heated, it yields phosphoric acid and phosphoretted hydrogen :—



2. It absorbs oxygen from the air, yielding phosphoric acid :—



PHOSPHORIC ANHYDRIDE.



Molecular weight = 142.

Preparation.—By burning phosphorus in excess of dry air or oxygen.

Reaction.—By contact with water it forms metaphosphoric acid:—



METAPHOSPHORIC ACID.



Molecular weight = 80.

Preparation.—1. By dissolving phosphoric anhydride in water (see above).

2. By heating phosphoric acid to redness:—



Preparation of metaphosphates.—The metaphosphates may be produced—

1. By igniting a dihydric phosphate with a fixed base:—



2. By igniting a monohydric phosphate which contains one atom of a volatile base:—



3. By igniting a dihydric pyrophosphate:—

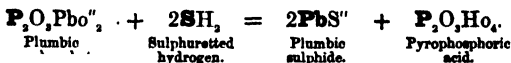


PYROPHOSPHORIC ACID.



Molecular weight = 178.

Preparation.—1. By decomposing plumbic pyrophosphate by hydrosulphuric acid :—



2. By heating tribasic phosphoric acid to 218° .

Pyrophosphates are prepared by heating monohydric phosphates containing two atoms of a monad metal :—

PHOSPHORIC ACID, *Tribasic Phosphoric Acid*.

Molecular weight = 98.

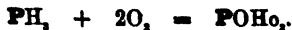
Preparation.—1. By boiling a solution of phosphoric anhydride or of metaphosphoric acid in water :—



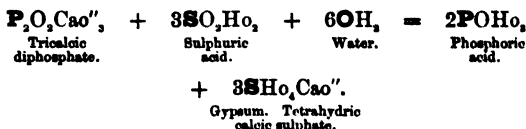
2. By the oxidation of amorphous phosphorus with nitric acid, and then boiling the product with water.

8. By the action of water upon phosphoric chloride and phosphoric oxytrichloride (see pp. 116 and 117).

4. By the combustion of phosphoretted hydrogen in air or oxygen :—



5. By decomposing tricalcic diphosphate (bone-ash) with a large excess of sulphuric acid :—



Reaction.—When heated to 213° it produces pyrophosphoric acid :—



The phosphates are a numerous and important class of salts. The following list contains some of the most interesting :—

Common sodic phosphate } (Hydric disodic phosphate) }	$\text{POHoNa}_2, 12\text{OH}_2.$
Trisodic phosphate.....	$\text{PONa}_3, 12\text{OH}_2.$
Hydric sodic potassic phosphate	$\text{POHoNaOKo}, \text{OH}_2.$
Apatite (<i>Francolite</i>)	$\text{P}_3\text{O}_5\text{Cao}'' \left(\begin{smallmatrix} \text{O} \\ \text{F} \end{smallmatrix} \text{Ca}'' \right).$
Triple phosphate (<i>Ammonic</i> } <i>magnesian phosphate</i>)	$\text{POAmoMgo}''.$
Vivianite.....	$\text{P}_2\text{O}_5\text{Feo}''., 8\text{OH}_2.$
Wavellite	$\text{P}_4\text{O}(' \text{Al}'' \text{O}_2)_3^{\text{vi}}, 12\text{OH}_2.$
Pyromorphite.....	$\text{P}_3\text{O}_5\text{Pb}$

VANADIUM, V, ?

Atomic weight = 51.3. *Probable molecular weight* = 205.2.

Atomicity "" and '. *Evidence of atomicity* :—

Vanadous chloride.....	$\text{V}'''\text{Cl}_2.$
Vanadic oxychloride	$\text{V}'\text{OCl}_2.$

Occurrence.—Sparsely in some lead- and iron-ores.

Preparation.—By heating to bright redness vanadous chloride in a current of dry hydrogen.



The following list contains the names and formulæ of the remaining chief compounds of vanadium:—

Hypovanadous chloride	$\left\{ \begin{array}{l} \text{VCl}_2 \\ \text{VCl}_2 \end{array} \right.$
Hypovanadous oxide	V_2O_2 .
Hypovanadic chloride	VCl_4 or $\left\{ \begin{array}{l} \text{VCl}_4 \\ \text{VCl}_4 \end{array} \right.$
Vanadous oxide	
Hypovanadic oxide	
Vanadic anhydride	V_2O_5 .
Metavanadic acid	VO_2Ho .
Tribasic vanadic acid	VOHo_2 .
Pyrovanadic acid	$\text{V}_2\text{O}_5\text{Ho}_2$.

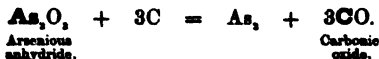
ARSENIC, As.

Atomic weight = 75. *Molecular weight* = 300. *Molecular volume* $\square\square$. 1 litre of arsenic vapour weighs 150 criths. *Sp. gr.* 5.6 to 5.9. *Volatile at* 180°. *Atomicity* ' and '.
Evidence of atomicity:—

Arseniuretted hydrogen	$\text{As}^{\text{III}}\text{H}_3$.
Arsenious chloride	$\text{As}^{\text{III}}\text{Cl}_3$.
Tetrethylarsonic chloride	$\text{As}^{\text{V}}\text{Et}_4\text{Cl}$.

Occurrence.—Abundantly in nature, in various ores, and sometimes in the free state. In some mineral waters, and in the water and mud of many rivers. In coal-smoke, and consequently in the air of towns.

Preparation.—By reducing, with charcoal, arsenious anhydride, which is produced in the roasting of many ores:—

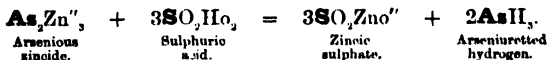


COMPOUND OF ARSENIC WITH HYDROGEN.

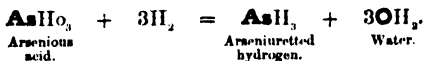
ARSENIURETTED HYDROGEN, *Arsenious Hydride*.

Molecular weight = 78. *Molecular volume* $\square\square$. 1 litre weighs 39 criths. *Boils at* -40° .

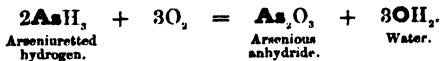
Preparation.—1. In the pure state by the action of sulphuric acid on an alloy of arsenic and zinc :—



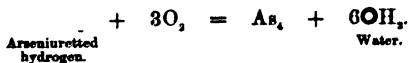
2. By the action of nascent hydrogen upon soluble arsenic compounds, as by the introduction of arsenious acid into an apparatus evolving hydrogen :—



Reactions.—1. When burnt with free access of air, it gives water and arsenious anhydride :—



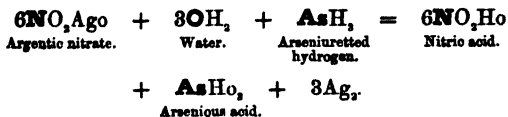
2. When burnt with a limited supply of air, it yields water and free arsenic :—



3. When exposed to a red heat, it is decomposed into arsenic and hydrogen.

4. Passed through a solution of argentic nitrate, it yields

a precipitate of metallic silver, arsenious and nitric acids remaining in solution :—

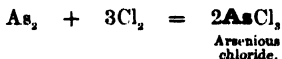


COMPOUND OF ARSENIC WITH CHLORINE.

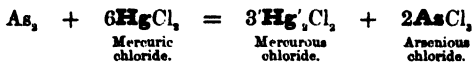
ARSENIOUS CHLORIDE.

Molecular weight = 181.5. *Molecular volume* $\square\square$. 1 litre of arsenious chloride vapour weighs 90.75 criths. *Sp. gr.* 2.205. *Boils at* 132°.

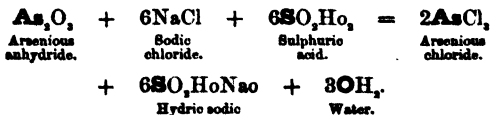
Preparation.—1. By the action of dry chlorine upon arsenic :—



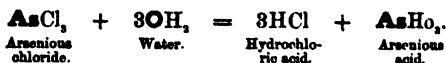
2. By distilling arsenic with mercuric chloride (corrosive sublimate) :—



3. By distilling sodic chloride, arsenious anhydride, and sulphuric acid :—



Reaction.—With excess of water it forms arsenious and hydrochloric acids :—



COMPOUNDS OF ARSENIC WITH OXYGEN AND HYDROXYL.

Arsenious anhydride (As_2O_3).

Arsenic anhydride As_2O_5 .

Arsenious acid..... AsHO_3 .

Arsenic acid..... AsO_5H .

ARSENIOUS ANHYDRIDE, *Arsenic, White Arsenic, White Oxide of Arsenic.*



Molecular weight = 396. *Molecular volume* $\square\square$. 1 litre of arsenious anhydride vapour weighs 198 criths. *Sp. gr.* 3.7.

Occurrence.—Very rare in nature.

Preparation.—1. By burning arsenic in air or oxygen.

2. By roasting arsenical ores in certain metallurgical operations.

ARSENIOUS ACID.



Molecular weight = 126.

Only known in solution.

Arsenious acid forms many unstable and difficultly crystallizable salts, of which the following are examples :—

Dihydric potassic arsenite (*Fowler's solution*) AsHO_3Ko .

Hydric cupric arsenite (*Scheele's green*) AsHO_3CuO .

Triargentate arsenite AsAgO_3 .

A monobasic arsenious acid, AsOHo , corresponding to nitrous acid, appears to exist, one of its compounds, AsOAmo , being known: Arsenious acid when boiled with cupric acetate yields Schweinfurt green, $3\text{As}_2\text{O}_3\text{CuO}$, $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$.

ARSENIC ANHYDRIDE.



Molecular weight = 230.

Preparation.—By heating arsenic acid nearly to redness:—



ARSENIC ACID.

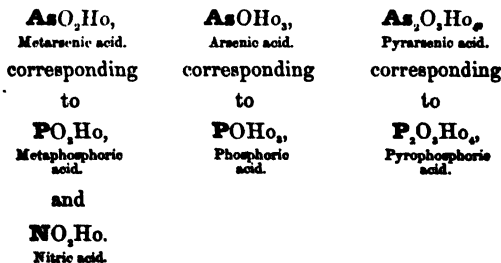


Molecular weight = 142.

Preparation.—By treating arsenious anhydride with nitric acid:—



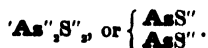
Salts are known which are derived from three acids of the following formulæ:—



**COMPOUNDS OF ARSENIC WITH SULPHUR AND
HYDROSULPHYL.**

Realgar	$\left\{ \begin{array}{l} \text{AsS}'' \\ \text{AsS}'' \end{array} = \text{'As''}, \text{S''} \right.$
Sulpharsenious anhydride (<i>Arsenious sulphide</i>)	$\text{As}_2\text{S''}_2$
Sulpharsenic anhydride (<i>Arsenic sulphide</i>)	$\text{As}_2\text{S''}_2$
Sulpharsenious acid	AsH_3
Sulpharsenic acid	$\text{AsS}''\text{H}_3$

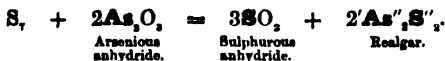
REALGAR, Diarsenious Disulphide.



Molecular weight = 214. *Sp. gr.* 3.5.

Occurrence.—Found native.

Preparation.—By heating sulphur with arsenious anhydride:—



SULPHARSENIOUS ANHYDRIDE, Arsenious Sulphide,

Orpiment.



Molecular weight = 246. *Sp. gr.* 3.5.

Occurrence.—Found native.

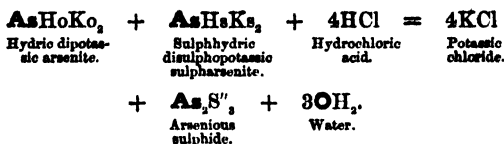
Preparation.—By passing sulphuretted hydrogen through a solution of arsenious anhydride in hydrochloric acid:—



Reaction.—Arsenious sulphide dissolves in caustic alkali, producing an arsenite and a sulpharsenite:—



By the addition of an acid, the arsenious sulphide is reprecipitated:—



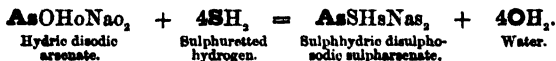
Proustite is a native trisulphargentic sulpharsenite, AsAg_3 .

SULPHARSENIC ANHYDRIDE, *Arsenic Sulphide*.



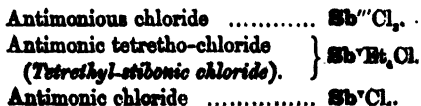
Molecular weight = 310.

Preparation.—By fusing together arsenious sulphide and sulphur. Sulpharsenates may be obtained by passing sulphuretted hydrogen through solutions of arsenates:—



ANTIMONY, Sb , ?

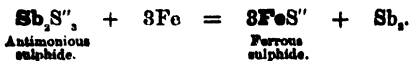
Atomic weight = 122. *Probable molecular weight* = 488. *Sp. gr. crystalline* 6·7, *amorphous* 5·78. *Fuses at* 430°. *Atomicity* "" and '. *Evidence of atomicity*:—



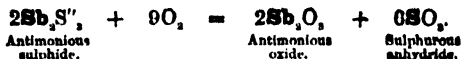
Occurrence.—To a small extent in the native state. Alloyed with metals in a few minerals. Sometimes in the form of oxide, but principally in the form of grey antimony ore or *stibnite*, which consists of antimonious sulphide.

a. Crystalline Antimony.

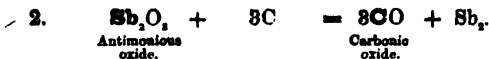
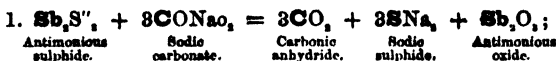
Preparation.—1. By fusing the native sulphide and introducing metallic iron, which combines with the sulphur:—



2. The native sulphide is roasted in contact with the air, when it is partially converted into antimonious oxide:—



The roasted mineral is then fused with charcoal and sodic carbonate. The reaction takes place in two stages: first, the remaining sulphide is converted into oxide by the sodic carbonate, and subsequently the oxide is reduced by the carbon:—



3. Antimony may be obtained in the pure condition by reducing, with charcoal, the oxide formed by the action of nitric acid upon crude antimony.

β. Amorphous Antimony.

Preparation.—By the electrolysis of a solution of tartar emetic in antimonious chloride.

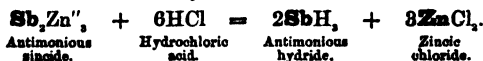
COMPOUND OF ANTIMONY WITH HYDROGEN.

ANTIMONIURETTED HYDROGEN, *Antimonious Hydride*.

Molecular weight = 125.

This compound is unknown in the pure condition.

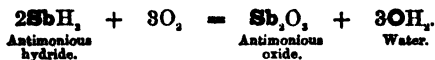
Preparation.—1. By the action of hydrochloric acid upon an alloy of zinc and antimony:—



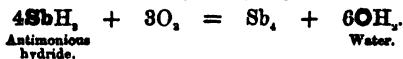
2. By the action of nascent hydrogen evolved from zinc and sulphuric acid upon soluble antimony compounds. In both these reactions the antimonious hydride is always mixed with much hydrogen:—



Reactions.—1. When burnt in air or in oxygen, it yields water and antimonious oxide:—

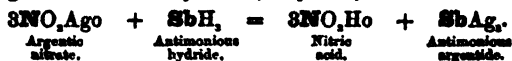


2. When burnt with a limited supply of air the hydrogen only is oxidized, the antimony being deposited:—



3. Decomposed into its elements, like arsenious hydride, when passed through a red-hot tube.

4. When transmitted through a solution of argentic nitrate, it produces a precipitate of antimonious argentide, thus differing from arsenious hydride (see p. 125):—



From the composition of this compound, and from that of some of its analogues, the composition of antimonious hydride is inferred.

Antimonious hydride.....	SbH₃.
Antimonious bromide	SbBr₃.
Antimonious argentide ..	SbAg₃.
Antimonious ziucide	Sb₂Zn²⁺.
Antimonious ethide. (<i>Triethylstibine</i> .)	SbEt₃.
Antimonious amylide. (<i>Triamylstibine</i> .)	SbAy₃.

COMPOUNDS OF ANTIMONY WITH CHLORINE.

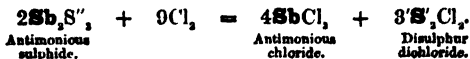
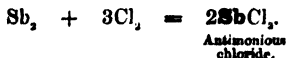
Antimonious chloride	SbCl_3 .
Antimonic chloride	SbCl_5 .

ANTIMONIOUS CHLORIDE.

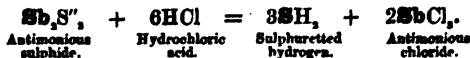


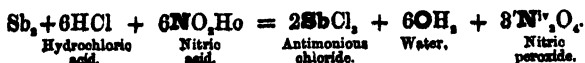
Molecular weight = 228.5. Molecular volume $\square\square$. 1 litre of antimonious chloride vapour weighs 114.25 criths. Fuses at 72°. Boils at 223°.

Preparation.—1. By passing chlorine over excess of metallic antimony or antimonious sulphide, and purifying by distillation:—

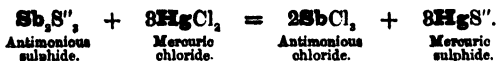
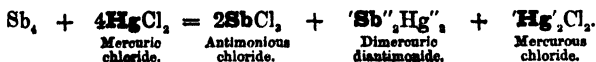


2. By dissolving antimonious sulphide in hydrochloric acid, or antimony in hydrochloric acid containing a little nitric acid, evaporating and distilling the product :—

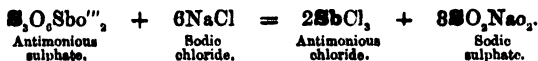




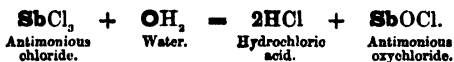
3. By distilling antimony or antimonious sulphide with mercuric chloride:—



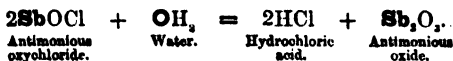
4. By distilling antimonious sulphate with sodic chloride:—



Reaction.—With water it produces antimonious oxychloride:—



Long-continued action of water transforms this compound into antimonious oxide:—

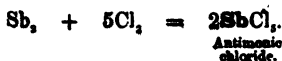


ANTIMONIC CHLORIDE.

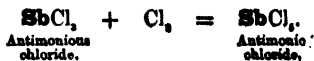


Molecular weight = 299.5. *Fuses at* 0°.

Preparation.—1. By acting upon antimony with excess of chlorine:—



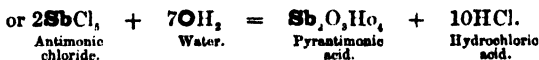
2. By passing chlorine over antimonious chloride, the latter liquefies, producing antimonie chloride :—



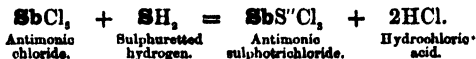
Reactions.—1. With a small quantity of water it forms antimonie oxytrichloride, analogous to phosphoric oxytrichloride :—



2. An excess of water transforms antimonie chloride into orthantimonie acid or pyrantimonie acid, corresponding to pyrophosphoric acid :—



3. By the action of sulphuretted hydrogen antimonie sulphotrichloride is formed :—

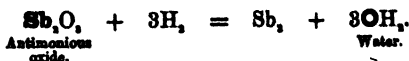
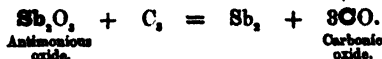


Antimonious bromide, SbBr_3 , resembles antimonious chloride; it fuses at 90° , boils at 270° , and by the action of water is converted into the *oxybromide*, SbOBr .

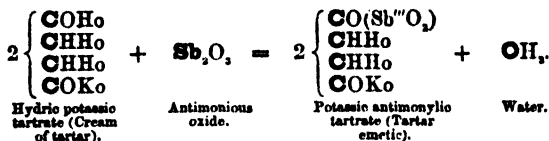
Antimonious iodide, SbI_3 , when acted upon by water forms the *oxyiodide*, SbOI .

The corresponding *fluoride*, SbF_3 , is said to exist and to be soluble in water without decomposition.

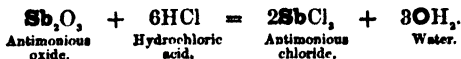
2. Readily reduced to the metallic state by ignition with charcoal, hydrogen, &c.



3. Readily dissolved by a hot solution of hydric potassic tartrate (cream of tartar), forming potassic antimonylic tartrate (tartar emetic):—



4. Dissolved by hydrochloric acid, forming antimonious chloride:—

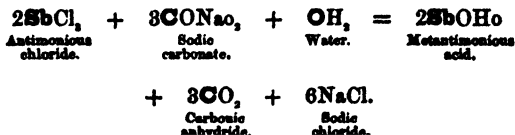


METANTIMONIOUS ACID.



Molecular weight = 155.

Preparation.—By pouring a solution of antimonious chloride into a cold solution of sodic carbonate:—



Reactions.—1. Decomposed by heat (page 186).

2. Readily dissolved by *alkaline hydrates*, producing ill-defined antimonites.

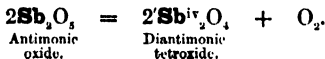
DIANTIMONIC TETROXIDE.



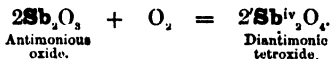
Molecular weight = 308.

Occurrence.—Found native as *cervantite*.

Preparation.—1. By igniting antimonious oxide, or the white solid produced by the action of nitric acid upon metallic antimony :—



2. By heating antimonious oxide in contact with the air :—

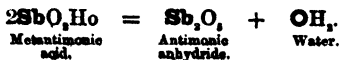
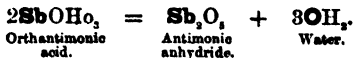


ANTIMONIC ANHYDRIDE.



Molecular weight = 324. *Sp. gr.* 6.6.

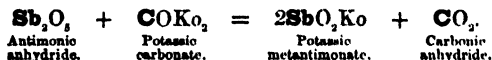
Preparation.—By gently heating the corresponding acids :—





Reactions.—1. When heated, it is decomposed into diantimonie tetroxide and oxygen (see page 138).

2. Fused with potassic carbonate, it produces potassic metantimoniate :—



ORTHANTIMONIC ACID ?

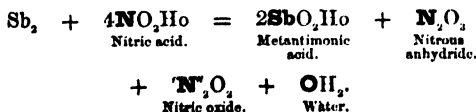


Preparation.—Said to be formed by the action of water upon antimonie chloride (see p. 135).

METANTIMONIC ACID.



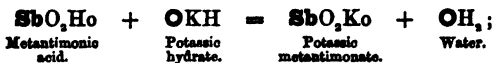
Preparation.—1. By the action of nitric acid containing a little hydrochloric acid on metallic antimony :—



2. By the spontaneous dehydration of orthantimonie acid, or of pyrantimonic acid :—



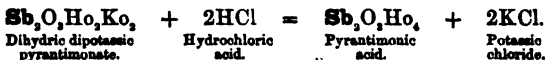
Reaction.—By the action of alkaline hydrates it produces either metantimonates or orthantimonates:—



PYRANTIMONIC ACID, *Parantimonio Acid.*
(*Metantimonio acid of Frémy.*)



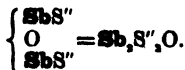
Preparation.—By acidifying solutions of pyrantimonates:—



Dihydric dipotassic pyrantimonate is prepared by fusing antimonio anhydride with excess of potassic hydrate, and extracting the mass with water, when an alkaline solution containing dihydric dipotassic pyrantimonate $\text{Sb}_2\text{O}_3\text{Ho}_2\text{Ko}_2$ is formed. This solution produces precipitates in solutions of sodium salts, the sodic pyrantimonate thus formed containing $\text{Sb}_2\text{O}_3\text{Ho}_2\text{Na}_2, 6\text{OH}_2$.

**COMPOUND OF ANTIMONY WITH OXYGEN
AND SULPHUR.**

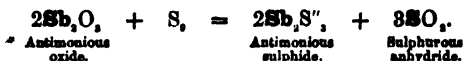
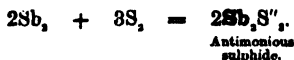
ANTIMONIOUS OXYDISULPHIDE.



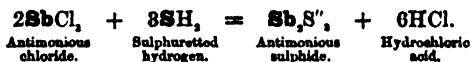
Molecular weight = 324.

Occurs as a rare mineral known as *red antimony*.

COMPOUNDS OF ANTIMONY AND SULPHUR.

Antimonious sulphide Sb_2S_3 .Antimonic sulphide Sb_2S_5 .ANTIMONIOUS SULPHIDE, *Sulphantimonious Anhydride*.*Molecular weight* = 340.*Occurrence*.—In nature as *stibnite* or *grey antimony ore*.*Preparation*.—1. By heating together antimony and sulphur, or antimonious oxide and sulphur, in the proper proportions :—

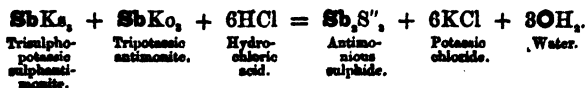
2. By passing sulphuretted hydrogen through a solution of antimonious chloride :—

*Reactions*.—1. Decomposed by hot hydrochloric acid (see p. 133).

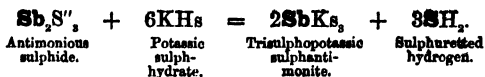
2. Soluble with decomposition in solutions of alkaline hydrates :—



Addition of an acid reproduces and precipitates the antimonious sulphide :—



3. Soluble in alkaline sulphhydrates:—



SULPHANTIMONITES.

Many sulphantimonites occur in nature:—

Orthosulphantimonites.

General formulæ:— SbMs_3 and $\text{Sb}_2\text{Ms}''_3$.

Dark-red silver. <i>Trisulphargentic sulphantimonite</i>	SbAg_3s_3 .
Boulangerite. <i>Trisulphoplumbic sulphantimonite</i>	$\text{Sb}_2\text{Pbs}'_3$.
Bournonite. <i>Disulphoplumbic sulphocuprous sulphantimonite</i>	$\text{Sb}_2\text{Pbs}''_2(\text{Cu}_2\text{S}''_2)''$.

Metasulphantimonites.

General formulæ:— $\text{SbS}''\text{Ms}$ and $\text{Sb}_2\text{S}''_2\text{Ms}''$.

Miargyrite. <i>Sulphargentic metasulphantimonite</i>	$\text{SbS}''\text{Ag}_3$.
Zinkenite. <i>Sulphoplumbic metasulphantimonite</i>	$\text{Sb}_2\text{S}''_2\text{Pbs}''$.
Antimony copper glance. <i>Sulphocuprous metasulphantimonite</i>	$\text{Sb}_2\text{S}''_2(\text{Cu}_2\text{S}''_2)''$.
Berthierite. <i>Sulphoferrous metasulphantimonite</i>	$\text{Sb}_2\text{S}''_2\text{FeS}''$.

Pyrosulphantimonites.

General formulæ:— $\text{Sb}_2\text{S}''\text{Ms}_3$ and $\text{Sb}_2\text{S}''\text{Ms}''_3$.

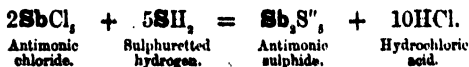
Feather ore. <i>Sulphoplumbic pyrosulphantimonite</i>	$\text{Sb}_2\text{S}''\text{Pbs}''_3$.
Fahl ore. <i>Sulphocuproferrous pyrosulphantimonite</i>	$\text{Sb}_2\text{S}''(\text{Cu}_2\text{FeS}''_2)''$.

ANTIMONIC SULPHIDE, *Sulphantimonic Anhydride.*

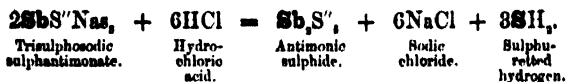


Molecular weight = 404.

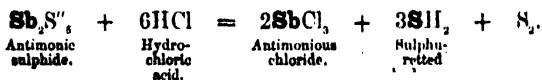
Preparation.—1. By passing sulphuretted hydrogen through a solution of antimonious chloride:—



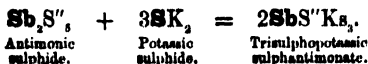
2. By the addition of an acid to a solution of a sulphantimonate:—



Reactions.—1. Decomposed by boiling hydrochloric acid, into antimonious chloride, sulphuretted hydrogen, and sulphur:—



2. Soluble in solutions of alkaline sulphides:—



3. Soluble in solutions of alkaline hydrates:—



BISMUTH, Bi?

Atomic weight = 209. *Sp. gr.* 9.83. *Fuses at* 265°. *Atomicity* " and √. *Evidence of atomicity* :—

Bismuthous chloride	$\text{Bi}^{\text{III}}\text{Cl}_3$.
Bismuthous oxide	$\text{Bi}^{\text{III}}_2\text{O}_3$.
Bismuthous ethide	$\text{Bi}^{\text{III}}\text{Et}_3$.
Bismuthous dichlorethide.....	$\text{Bi}^{\text{III}}\text{EtCl}_2$.
Bismuthic anhydride.....	Bi_2O_3 .

Occurrence.—Principally in the metallic state in nature.

Preparation.—1. On a large scale by fusion and separation from earthy impurities.

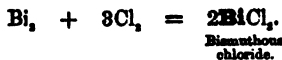
2. It may be obtained in the pure state by dissolving commercial bismuth in nitric acid, precipitating the basic nitrate by addition of water, and reducing the precipitate by ignition with charcoal.

No compound of bismuth with hydrogen is known.

COMPOUND OF BISMUTH WITH CHLORINE.**✓ BISMUTHOUS CHLORIDE.**

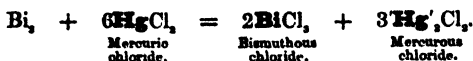
Molecular weight = 314.5. *Molecular volume* $\square\square$. 1 litre of bismuthous chloride vapour weighs 157.25 grs.

Preparation.—1. By passing dry chlorine over metallic bismuth :—

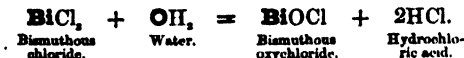


2. By evaporating a solution of bismuth in hydrochloric acid containing a little nitric acid and distilling.

3. By distilling metallic bismuth with mercuric chloride:—



Reaction.—By the addition of water it is decomposed, forming bismuthous oxychloride:—



The following compounds are also known:—

Bismuthous bromide	BiBr_3 .
Bismuthous iodide	BiI_3 .
Bismuthous fluoride	BiF_3 .
Bismuthous oxybromide	BiOBr .
Bismuthous oxyiodide	BiOI .
Dibismuthous tetrachloride.....	$\left\{ \begin{array}{l} \text{BiCl}_2 \\ \text{BiCl}_3 \end{array} \right.$

COMPOUNDS OF BISMUTH WITH OXYGEN AND HYDROXYL.

Dibismuthous dioxide	$\left\{ \begin{array}{l} \text{BiO} \\ \text{BiO} \end{array} \right.$
Bismuthous oxide	Bi_2O_3 .
Dibismuthic tetroxide	$\text{Bi}^{\text{iv}}_2\text{O}_4$.
Bismuthic anhydride	Bi_2O_5 .
Bismuthous oxyhydrate, or meta- bismuthous acid	BiOHO .
Metabismuthic acid	BiO_2H .

BISMUTHOUS OXIDE.

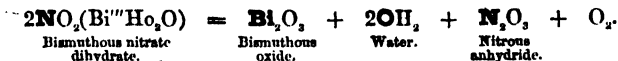
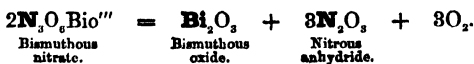


Molecular weight = 464. *Sp. gr.* 8.2.

Occurrence.—As the rare mineral *bismuth ochre*.

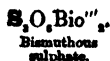
Preparation.—1. By burning bismuth in air or oxygen.

2. By heating the nitrate, carbonate, or hydrate:—



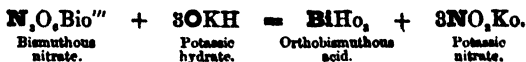
3. By boiling bismuthous hydrate in solution of potassic hydrate, whereby it is converted into bismuthous oxide with loss of water.

Reactions.—Dissolved by hydrochloric, nitric, and sulphuric acids, forming the bismuthous chloride, nitrate, and sulphate:—

BISMUTHOUS OXYHYDRATE, *Metabismuthous Acid*.

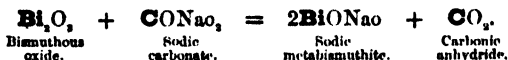
Preparation.—By pouring a solution of bismuthous nitrat

in dilute nitric acid into dilute ammonia or potassic hydrate, and drying the precipitate, which, at first, probably contains orthobismuthous acid:—



Reaction.—By heat or by boiling with caustic alkali, water is expelled, and bismuthous oxide formed (see p. 146).

An unstable metabismuthite is produced by fusing bismuthous oxide with sodic carbonate:—



BISMUTHIC ANHYDRIDE.



Preparation.—By heating bismuthic acid to 130°.

Reactions.—1. When heated to the boiling-point of mercury, it loses oxygen, being converted either into bismuthous oxide or dibismuthic tetroxide:—



2. When heated in a current of hydrogen, it is readily reduced to bismuthous oxide.

3. Heated with hydrochloric acid, it evolves chlorine, producing bismuthous chloride and water :—



4. Sulphurous acid converts it into bismuthous sulphate :—



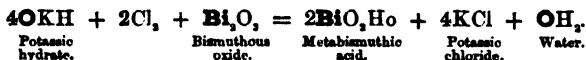
5. When heated with sulphuric or nitric acid, it evolves oxygen, producing bismuthous sulphate or nitrate :—



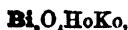
METABISMUTHIC ACID.



Preparation.—Obtained as a red deposit by passing chlorine through a solution of potassic hydrate containing bismuthous oxide in suspension :—



Reaction.—Dissolves in hot solution of potassic hydrate. By the addition of an acid to the liquid, a salt, said to have the composition

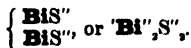


is precipitated.

COMPOUND OF BISMUTH WITH SULPHUR.

Dibismuthous disulphide $\text{Bi}''_2\text{S}''_2$.Bismuthous sulphide $\text{Bi}_2\text{S}''_3$.

DIBISMUTHOUS DISULPHIDE.

*Molecular weight* = 480. *Sp. gr.* 7.3.

Preparation.—By fusing bismuth and sulphur together in the proper proportions.

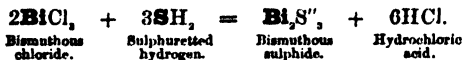
BISMUTHOUS SULPHIDE.

*Molecular weight* = 512. *Sp. gr.* 6.4.

Occurrence.—As the rare mineral *bismuth glance*.

Preparation.—1. By fusing sulphur and bismuth in the proper proportions.

2. By precipitating bismuth solutions by sulphuretted hydrogen:—

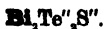


Reaction.—This compound is not dissolved by alkaline hydrates or sulphydrates.

A few sulphobismuthites are found in nature:—

Kobellite. <i>Trisulphoplumbic sulphobismuthite</i>	}	$\text{Bi}_2\text{Pbs}''_3$.
Needle ore. <i>Disulphoplumbic-dicuprous sulphobismuthite</i>	}	$\text{Bi}_2\text{Pbs}''_3(\text{Cu}'_2\text{S}_3)''$.

BISMUTHOUS DITELLURO-SULPHIDE.



Sp. gr. 7.5 to 7.8.

Occurrence.—In nature, as *telluric bismuth* or *tetradymite*.

CHAPTER XVII.

MONAD ELEMENTS.

SECTION III.

POTASSIUM, K.

Atomic weight = 39. *Probable molecular weight* = 78. *Sp. gr.* 0.865. *Fuses* at 55°. *Boils* at a low red heat. *Atomicity* 1.

Evidence of atomicity :—

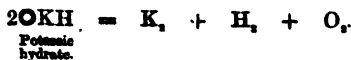
Potassic chloride	KCl.
Potassic iodide	KI.
Potassic hydrate	KHo.
Potassic sulphide	SK ₂ .

Occurrence.—In rocks in the form of silicate, and in soils partly as carbonate. As chloride in solid saline deposits.

In the juices of almost all plants, generally in combination with organic acids.

In sea-water and in most mineral waters.

Preparation.—1. By the action of a powerful voltaic current upon potassic hydrate, when potassium and hydrogen are liberated at the negative pole :—

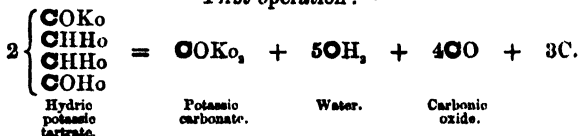


2. By submitting potassic hydrate to the action of metallic iron at a strong white heat :—

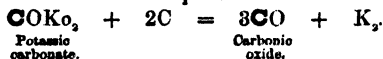


3. By igniting hydric potassic tartrate (cream of tartar) out of contact with air, and subsequently mixing the residue, consisting of potassic carbonate and carbon, with charcoal, and distilling at a very high temperature :—

First operation :—



Second operation :—



Reactions.—1. Potassium decomposes water even at its freezing-point with great energy, the heat evolved being sufficient to cause the ignition of the liberated hydrogen :—



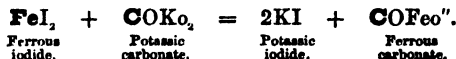
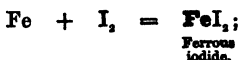
2. When potassium is ignited in a stream of carbonic anhydride, a portion of the latter is decomposed :—



COMPOUNDS OF POTASSIUM WITH CHLORINE, BROMINE, IODINE, AND FLUORINE.

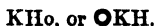
Potassic chloride	KCl.
Potassic bromide	KBr.
Potassic iodide	KI.
Potassic fluoride	KF.

Potassic iodide is prepared by digesting iron filings, water, and iodine together, filtering the colourless solution, and precipitating the iron by potassic carbonate:—



COMPOUND OF POTASSIUM WITH HYDROXYL.

POTASSIC HYDRATE, *Caustic Potash, Potash.*

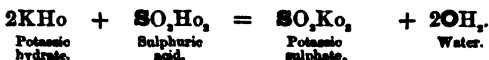
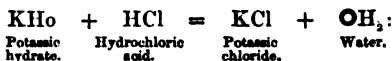


Preparation.—1. By boiling in an iron vessel a solution of potassic carbonate with calcic hydrate:—

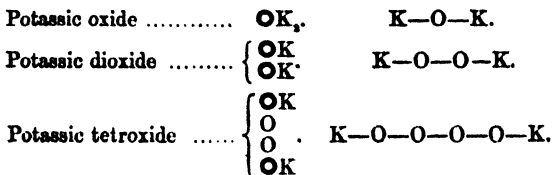


2. By the action of potassium upon water (see p. 151).

Reactions.—By contact with acids potassic hydrate produces potassium salts:—



COMPOUNDS OF POTASSIUM WITH OXYGEN.



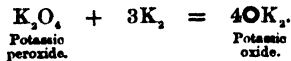
POTASSIC OXIDE.



Preparation.—1. By heating potassic hydrate with potassium:—



2. By fusing together, in a current of nitrogen, potassic peroxide and potassium:—



POTASSIC DIOXIDE.



Preparation.—Obtained by the action of water on potassic peroxide.

POTASSIC TETROXIDE, *Potassic Peroxide.*



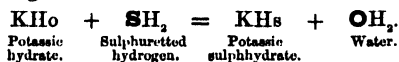
Preparation.—By fusing potassium in a current of oxygen.

COMPOUND OF POTASSIUM WITH HYDRO-SULPHYL.

POTASSIC SULPHHYDRATE.

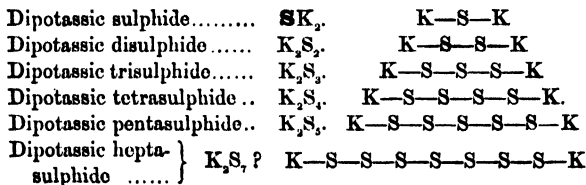


Preparation.—By saturating potassic hydrate with sulphuretted hydrogen:—



COMPOUNDS OF POTASSIUM WITH SULPHUR.

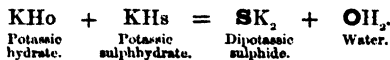
The following have been obtained:—



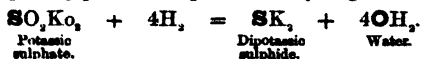
DIPOTASSIC SULPHIDE.



Preparation.—1. By the action of potassic hydrate on potassic sulphhydrate:—

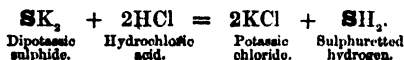
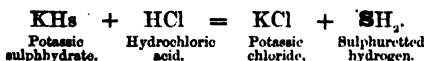


2. By igniting potassic sulphate with hydrogen or carbon:—

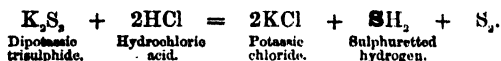


Reactions of dipotassic sulphide and the higher potassic sulphides:—1. By heating dipotassic sulphide with the necessary quantities of sulphur, it forms the higher potassic sulphides.

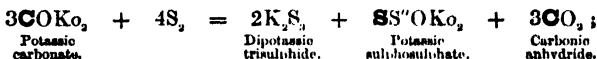
2. The potassic sulphhydrate and dipotassic sulphide, when acted upon by acids, yield sulphuretted hydrogen:—



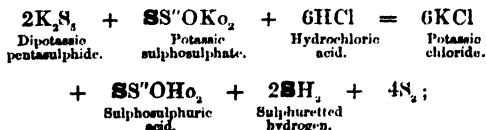
3. The higher potassic sulphides, similarly treated, yield sulphuretted hydrogen and a precipitate of sulphur:—



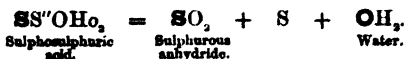
4. A mixture of the higher potassic sulphides and potassic hyposulphite, known under the name of *hepar sulphuris* or *liver of sulphur*, may be prepared by heating potassic carbonate with sulphur:—



5. The last mixture, when acted upon by acids, suffers successively the following decompositions:—



then



POTASSIC CARBONATE.

- Preparation.*—1. By lixiviating the ashes of land-plants.
2. By burning hydric potassic tartrate in a current of air.

SODIUM, Na.

Atomic weight = 23. *Probable molecular weight* = 46. *Sp. gr.* 0.97. *Fuses at* 90°. *Boils at a red heat.* *Atomicity* 1.
Evidence of atomicity :—

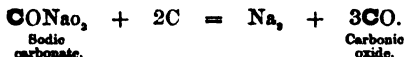
Sodic chloride.....	NaCl.
Sodic hydrate.....	ONaH.
Sodic oxide	ONa ₂ .

Occurrence.—In nature in the form of chloride. In sea-water and most springs. As silicate in several minerals.

Preparation.—1. By electrolyzing sodic hydrate.

2. By acting upon sodic hydrate with metallic iron at a strong white heat.

Manufacture.—By distilling in an iron retort a mixture of sodic carbonate, chalk, and charcoal :—



Reactions.—Similar to those of potassium, but less energetic. The compounds of sodium very much resemble those of potassium.

SODIC CARBONATE.

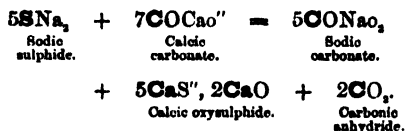
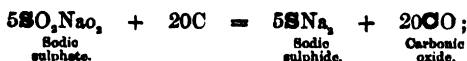
Manufacture.—1. Formerly by the lixiviation of the ashes of marine plants.

2. By Leblanc's process, which consists in first transforming

sodic chloride into sodic sulphate by the action of sulphuric acid :—



The sodic sulphate (technically termed *salt cake*) is next heated with calcic carbonate and small coal. The carbon reduces the sodic sulphate to sulphide; and the calcic carbonate transforms the sodic sulphide into sodic carbonate, insoluble calcic oxysulphide being simultaneously produced :—



The sodic carbonate, commonly called *soda ash*, is obtained by the extraction of the resulting mass with water.

LITHIUM, Li.

Atomic weight = 7. *Probable molecular weight* = 14. *Sp. gr.* = 0.59. *Fuses at* 180°. *Atomicity* 1. *Evidence of atomicity* :—

Lithic chloride LiCl.
Lithic hydrate (Lithia) OLiH.

Occurrence.—In nature, in the minerals *petalite*, *evodumens*, *lepidolite*, and *triphylline*, and in small quantities in some mineral waters and ashes of plants.

The properties of lithium resemble those of potassium and sodium; and the compounds of the three metals also exhibit considerable similarity.

SECTION IV.

SILVER, Ag_2 .

Atomic weight = 108. *Probable molecular weight* = 216. *Sp. gr.* 10.4743. *Fuses* at about 1000° . *Atomicity* 1. *Evidence of atomicity* :—

Argentio chloride..... AgCl .
 Argentio iodide AgI .
 Argentio oxide OAg_2 .

Occurrence.—In nature in the free state, and as sulphide in *silver glance*; as sulphantimonite in *dark-red silver-ore* (see p. 142), as chloride in *horn-silver*, as a compound of bromide and chloride (2AgBr , 3AgCl) in *embolite*, and also as carbonate.

Extraction.—1. The silver minerals are roasted with sodic chloride, by which the metal is converted into chloride; the mass is then mixed with water, scrap iron, and mercury, and agitated for some hours. The iron reduces the argentio chloride to the metallic state, and the silver is then dissolved by the mercury.

2. By crystallizing argentiferous lead. Nearly pure lead is first deposited; and the residue, rich in silver, is then cupelled.

Reactions.—1. Silver is blackened by sulphuretted hydrogen, argentio sulphide being formed.

2. Silver is acted upon by hot concentrated sulphuric acid :—



3. Dilute nitric acid readily dissolves silver :—



4. At a red heat silver decomposes hydrochloric acid:—



There are three compounds of silver with oxygen:—

Argentous oxide	OAg_2 ?
Argentous oxide	OAg_2 .
Argentous peroxide	$\left\{ \begin{array}{l} \text{OAg} \\ \text{OAg} \end{array} \right.$

Argentous oxide is prepared by heating argentous citrate to 100° in a stream of hydrogen, dissolving the residue, which contains argentous citrate, in cold water, and precipitating the argentous oxide by potassic hydrate.

Argentous oxide is formed by precipitating argentous nitrate with a solution of baric hydrate, and drying the precipitate, which is probably argentous hydrate, AgHO . This is the salifiable oxide of silver.

Argentous peroxide is obtained by electrolyzing a solution of argentous nitrate, when it is deposited upon the positive pole.

Argentous chloride, bromide, and iodide are insoluble in water and nitric acid.

CHAPTER XVIII.

DIAD ELEMENTS.

SECTION II.

BARIUM, Ba.

Atomic weight = 137. Probable molecular weight = 137. Sp. gr. between 4.0 and 5.0. Fuses below a red heat. Atomicity".

Evidence of atomicity:—

Baric chloride	$\text{Ba}^{\text{II}}\text{Cl}_2$.
Baric hydrate	$\text{Ba}^{\text{II}}\text{HO}_2$.
Baric oxide	$\text{Ba}^{\text{II}}\text{O}$.

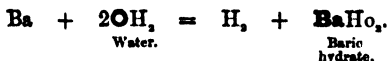
Occurrence.—In nature in the form of sulphate in the mineral *heavy spar*, and as carbonate (COBaO) in *witherite*.

Preparation.—1. By electrolyzing moistened baric hydrate, carbonate, nitrate, or chloride, the negative electrode being mercury. An amalgam of barium is thus formed, from which the mercury is removed by distillation.

2. By passing the vapour of potassium or sodium over baric oxide strongly heated in an iron tube, and extracting the metal by means of mercury.

3. By acting upon a solution of baric chloride with sodium amalgam, barium amalgam is produced.

Reaction.—Barium decomposes water at the common temperature :—



COMPOUNDS OF BARIUM WITH OXYGEN.

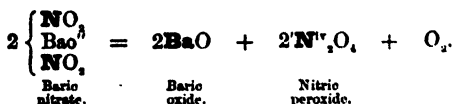
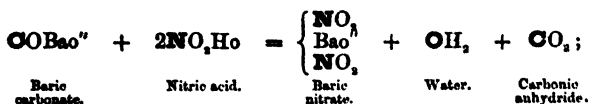
Baric oxide BaO . $\text{Ba}=\text{O}$

Baric peroxide $\text{Ba} \begin{smallmatrix} \text{O} \\ \text{O} \end{smallmatrix} \}$. $\text{Ba} \left\{ \begin{smallmatrix} \text{O} \\ \text{O} \end{smallmatrix} \right.$

BARYTA, *Baric Oxide*.

BaO .

Preparation.—1. By converting the native carbonate into nitrate by the action of nitric acid, and then heating the nitrate to redness in an iron crucible :—



2. The nitrate may be obtained from native baric sulphate by mixing the latter with charcoal and heating the mixture to a high red heat, by which the sulphate is converted into sulphide:—



the residue is then treated with dilute nitric acid, when baric nitrate is formed.

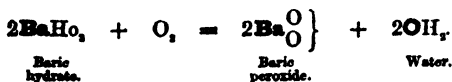
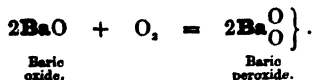
Reaction.—In contact with water, baric oxide is converted, with great evolution of heat, into baric hydrate:—



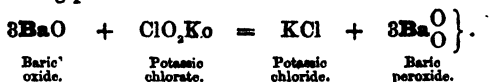
BARIC PEROXIDE.



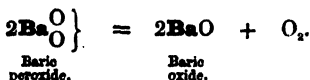
Preparation.—1. By passing oxygen over baric oxide or baric hydrate heated to dull redness:—



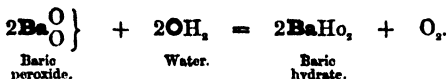
2. By heating baric oxide to redness in a crucible and gradually adding potassic chlorate :—



Reactions.—1. By the action of heat it splits into baric oxide and oxygen :—



2. By treatment with steam, at the same temperature at which the peroxide was previously formed, it produces baric hydrate and oxygen :—



3. By the action of carbonic anhydride or acids upon baric peroxide, hydroxyl is formed (p. 45).

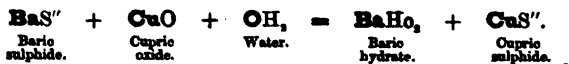
COMPOUND OF BARIUM WITH HYDROXYL.

BARIC HYDRATE, *Caustic Baryta.*



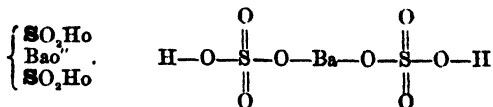
Preparation.—1. By the action of water on baric oxide (p. 161).

2. By boiling in water, with cupric oxide, the mass containing baric sulphide, prepared by reducing baric sulphate with carbon :—



Barium salts are formed by the action of acids upon baric hydrate, carbonate, or oxide.

DIHYDRIC BERIC DISULPHATE.



This compound is formed by boiling beric sulphate in concentrated sulphuric acid, when the salt crystallizes on cooling.

STRONTIUM, Sr.

Atomic weight = 87.5. *Probable molecular weight* = 87.5.

Sp. gr. 2.5. *Fuses at a higher temperature than barium.*

Atomicity ". *Evidence of atomicity* :—

Strontic chloride.....	Sr''Cl ₂ .
Strontic hydrate.....	Sr''Ho ₂ .
Strontic oxide.....	Sr''O.

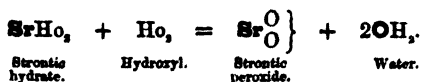
Occurrence.—In the form of carbonate as the mineral *strontianite*, and as sulphate in *celestine*.

Preparation.—1. By the same methods as those employed in the preparation of barium.

2. By electrolyzing fused strontic chloride.

Character.—The compounds of strontium resemble those of barium in constitution, preparation, and properties.

The *strontic peroxide* can only be prepared by adding hydroxyl to a solution of strontic hydrate :—



Strontic carbonate is more easily decomposed by heat than beric carbonate.

CALCIUM, Ca.

Atomic weight = 40. *Probable molecular weight* = 40. *Sp. gr.*

1.6. *Atomicity*". *Evidence of atomicity* :—

Calcic chloride	Ca"Cl ₂ .
Calcic hydrate	Ca"HO ₂ .
Calcic oxide	Ca"O.

Occurrence.—In nature as carbonate in the numerous *calc spars*, chalk, marble, &c.; as tetrahydric calcic sulphate (SHo₄CaO") in *gypsum*, *alabaster*, *selenite*, &c.; as phosphate in *apatite* and *phosphorite* (see p. 123); as fluoride in the *fluor spars* (see p. 98); and in combination with silicon, oxygen, and other metals in numerous minerals.

Preparation.—1. By processes similar to those employed for the preparation of barium and strontium.

2. By fusing together sodium, zinc, and calcic chloride, and subsequently heating the alloy of calcium and zinc so obtained, to a very high temperature in a crucible of gas-carbon, when the zinc volatilizes, leaving the calcium, which contains, however, a small quantity of iron.

Character.—The compounds of calcium resemble those of barium and strontium.

Calcic oxide or *quicklime* (CaO) is manufactured on a large scale by burning coal intermixed with chalk or limestone, when carbonic anhydride is easily expelled from the chalk or limestone, leaving calcic oxide.

Calcic hydrate or *slaked lime* (CaHO₂) is formed by the action of water upon calcic oxide; it is much less soluble in water than the baric and strontic hydrates.

—By exposing quicklime to the action of the air it is converted into *dicalcic carbonate dihydrate*, CO(OCa"HO)₂.

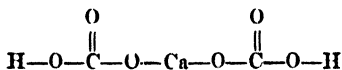
Calcic peroxide (Ca^O₂) is prepared like the corresponding strontium compound.

By passing chlorine over calcic hydrate, a compound known as *chloride of lime* or *bleaching-powder* is formed. This has been supposed to consist of calcic chloride mixed with calcic hypochlorite; but it is more probably calcic chloro-hypochlorite, as expressed by the following formulæ:—

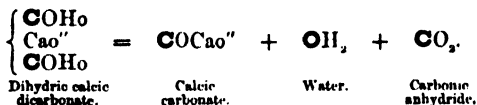


The corresponding baric and strontic chloro-hypochlorites $\text{Ba}\begin{smallmatrix}(\text{OCl})\\ \text{Cl}\end{smallmatrix}$ and $\text{Sr}\begin{smallmatrix}(\text{OCl})\\ \text{Cl}\end{smallmatrix}$, are known.

Barium, strontium, and calcium all form soluble dihydric dicarbonates:—



They are produced by passing an excess of carbonic anhydride through solutions of baric, strontic, and calcic hydrates. The compounds are decomposed at 100° , carbonic anhydride being evolved and carbonates precipitated:—



MAGNESIUM, Mg.

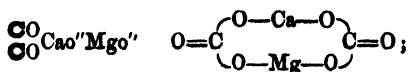
Atomic weight = 24. *Probable molecular weight* = 24. *Sp. gr.*

1.75. *Fuses at a red heat. Volatilizes at a bright red heat.*

Atomicity". *Evidence of atomicity*:—

Magnesium chloride	$\text{Mg}''\text{Cl}_2.$
Magnesium oxide	$\text{Mg}''\text{O}.$
Magnesium hydrate	$\text{Mg}''\text{H}_2\text{O}.$

Occurrence.—In nature in *dolomite*, the calcic magnesian dicarbonate,



in *brucite* or magnesian hydrate, MgHo_2 , and in many minerals containing silicon.

Preparation.—1. By electrolyzing fused magnesian chloride.

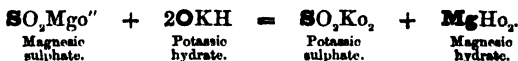
2. By fusing a mixture of magnesian chloride, potassic chloride, and sodium.

Reactions.—1. It very slowly decomposes water at the ordinary temperature, but more rapidly at a boiling heat.

2. It readily burns when heated to redness in the air.

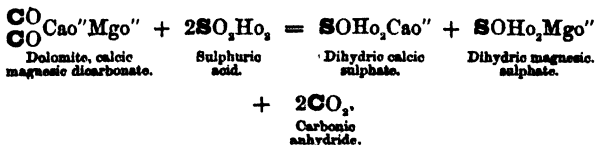
Character.—Magnesium only forms one compound with oxygen, MgO , *magnesia*. It is obtained by burning magnesium in air, or by heating the carbonate to redness.

Magnesian hydrate (MgHo_2) is formed by the action of water upon magnesian oxide, or by precipitating magnesian sulphate by potassic hydrate:—



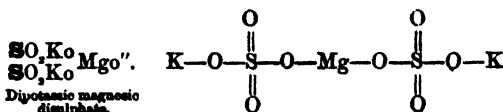
It scarcely dissolves in water.

Crystallized magnesian sulphate ($\text{SOHo}_2\text{Mgo''}$, 6OH_2) is prepared by treating *dolomite*, the magnesian calcic dicarbonate, with sulphuric acid, filtering from the nearly insoluble calcic sulphate, and crystallizing:—



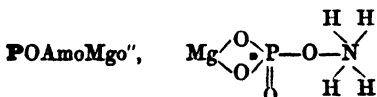
Magnesian sulphate is very soluble in water, thus differing from the baric, strontic, and calcic sulphates.

Magnesian sulphate, when mixed with potassic or ammoniac sulphate, forms a disulphate, as, for instance,



Many magnesian phosphates are known.

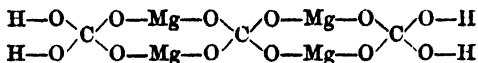
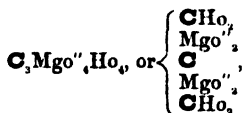
Ammoniac magnesian phosphate,



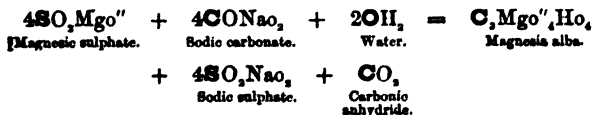
occurs in the seeds of some of the cereals, and sometimes in urine, and in urinary calculi: it is found in nature as *guanite* and *struvite*.

Magnesian carbonate (COMgo'') is found in nature as *magnesite*.

MAGNESIA ALBA, *Tetrahydric tetramagnesian tricarbonat*.



This compound is formed by boiling a solution of magnesian sulphate with sodic carbonate (Berzelius):—



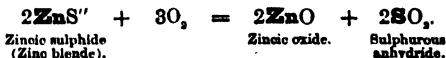
ZINC, Zn.

Atomic weight = 65. *Molecular weight* = 65. *Molecular and atomic volume* $\square\square$. 1 litre of zinc vapour weighs 82.5 criths. *Sp. gr.* 6.8 to 7.2. *Fuses* at 500°. *Distils* at a red heat. *Atomicity*". *Evidence of atomicity* :—

Zincic chloride	$\text{Zn}''\text{Cl}_2$.
Zincic oxide	$\text{Zn}''\text{O}$.
Zincic hydrate	$\text{Zn}''\text{HO}_2$.

Occurrence.—In nature as oxide (ZnO) in *red zinc*, as sulphide (ZnS'') in the mineral *zinc blende*, as carbonate (COZnO'') in *calamine*, and as silicate in *electric calamine*, *williamite*, or *zinc glass*.

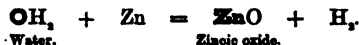
Manufacture.—Zinc blende, or calamine, by being roasted in a current of air, is converted into zincic oxide :—



The roasted and powdered mineral is then heated with powdered coal, when the zinc is reduced and distils over :—

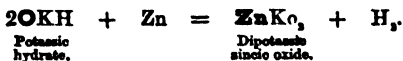


Reactions.—1. It slowly decomposes aqueous vapour at 100° :—



2. Zinc is attacked by almost every acid at the common temperature.

3. When boiled in potassic, sodic, or even ammoniac hydrate, hydrogen is evolved, and a double oxide formed:—



COMPOUND OF ZINC WITH OXYGEN.

ZINCIC OXIDE.



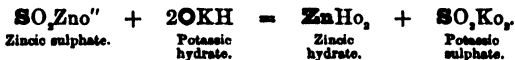
Preparation.—1. Zincic oxide is obtained by burning zinc in air.

2. By passing steam over heated zinc.

3. By heating the precipitate formed by ammoniac carbonate in solutions of zinc salts.

OTHER COMPOUNDS OF ZINC.

Zincic hydrate (ZnHo_2) is obtained as a white precipitate by the action of potassic hydrate on solutions of zinc salts:—



The precipitate is dissolved by excess of potassic hydrate.

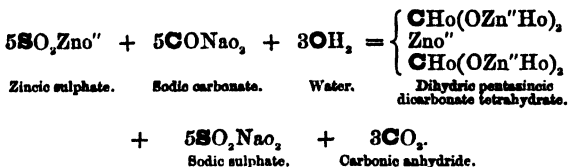
Crystallized zincic sulphate is isomorphous with crystallized magnesian sulphate, and contains seven molecules of water, six of which are easily expelled at a moderate heat, the last only being driven off at a somewhat high temperature. It also resembles magnesian sulphate in forming double salts with potassic and ammoniac sulphates:—

Zincic sulphate (crystallized) $\text{SOHo}_2\text{Zno}'', 6\text{OH}_2$.

Dipotassic zincic disulphate (crystallized) $\left\{ \begin{array}{l} \text{SO}_4\text{Ko} \\ \text{Zno}'' \\ \text{SO}_4\text{Ko} \end{array} \right., 6\text{OH}_2$.

Zinc carbonate (COZn'') occurs in nature as *calamine*.

The precipitate obtained by adding a solution of sodic carbonate to a solution of a salt of zinc has a variable constitution. The reaction usually takes place thus:—



CHAPTER XIX.

DYAD ELEMENTS.

SECTION IV.

CADMIUM, Cd.

Atomic weight = 112. *Molecular weight* = 112. *Molecular and atomic volume* $\square\square$. 1 litre of cadmium vapour weighs 56 criths. *Sp. gr.* 8.7. *Fuses* below 260° . *Easily volatile*. *Atomicity*". *Evidence of atomicity*:—

Cadmic chloride..... $\text{Cd}''\text{Cl}_2$.
 Cadmic oxide $\text{Cd}''\text{O}$.

Occurrence.—In nature in small quantities, associated with zinc, and in the form of sulphide as *greenockite*.

Preparation.—By distilling fractionally the more volatile part of the metal obtained in the manufacture of zinc, and then dissolving this more volatile product (which consists of

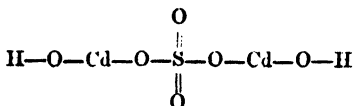
zinc, cadmium, and a little copper) in hydrochloric or dilute sulphuric acid, precipitating the cadmium and copper with sulphuretted hydrogen, dissolving the mixed sulphides in dilute sulphuric acid, and adding an excess of solution of ammoniac carbonate, which precipitates both cadmium and copper, but redissolves the latter. The cadmic carbonate is then ignited, and the resulting oxide reduced by charcoal.

Cadmia oxide (CdO) is prepared by heating the hydrate, carbonate, or nitrate.

Cadmia hydrate (CdH_2O_2) is obtained by precipitating a solution of a cadmic salt by sodic or potassic hydrate.

Cadmia sulphate ($\text{SO}_4\text{CdO}''$, 4OH_2) is obtained by dissolving cadmic oxide or carbonate in sulphuric acid. By heating this compound, or by partially decomposing it with alkaline hydrates, it is transformed into

Dicadmia sulphate dihydrate $\text{SO}_4(\text{OCd}''\text{H}_2\text{O})_2$



MERCURY, Hg.

Atomic weight = 200. *Molecular weight* = 200. *Molecular and atomic volume* $\square\square$. 1 litre of mercury vapour weighs 100 criths. *Sp. gr.* 13.59. *Fuses at* -40° . *Boils at* 360° . *Atomicity* ", also a pseudo-monad.

The following list contains the names and probable constitutional formulæ of the principal compounds of this metal:—

Mercurous chloride } $\text{Hg}'\text{Cl}_2$, or { $\begin{array}{c} \text{HgCl} \\ \text{HgCl} \end{array}$. $\text{Cl}-\text{Hg}-\text{Hg}-\text{Cl}$
(horn-mercury)

Mercuric chloride... HgCl_2 .

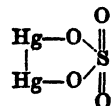
Mercurous oxide... $\text{Hg}'\text{O}$, or { $\begin{array}{c} \text{Hg} \\ \text{Hg} \end{array}$. $\begin{array}{c} \text{Hg} \\ | \\ \text{Hg} \end{array} \text{O}$

Mercuric oxide ... HgO . $\text{Hg}=\text{O}$

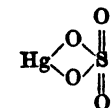
Mercurous sulphide Hg_2S , or $\left\{ \text{HgS} \right\}$.

Mercuric sulphide $\left. \begin{array}{l} \text{(vermilion, cinna-} \\ \text{bar)} \end{array} \right\} \text{HgS}$.

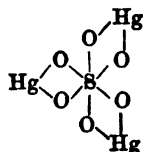
Mercurous sulphate. $\text{SO}_4(\text{Hg}_2\text{O}_2)''$.



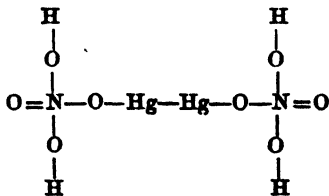
Mercuric sulphate... SO_4HgO .



Trimercuric sulphate $\left. \begin{array}{l} \text{(Turpeth mineral).} \end{array} \right\} \text{SHgO}$.



Tetrahydric mercurous dinitrate... $\text{N}_2\text{O}_4\text{Hg}_2(\text{Hg}_2\text{O}_2)''$.



Dimercurous dinitrate ... $\left\{ \begin{array}{l} \text{NO}(\text{Hg}_2\text{O}_2)' \\ \text{O} \\ \text{NO}(\text{Hg}_2\text{O}_2)'' \end{array} \right\}$.

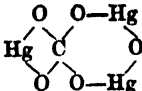
Hexahydric trimercu- } $\text{N}_2\text{O}_4\text{Ho}(\text{Hg}'\text{O}_2)''$.
rous tetranitrate ... }

Mercurous dimeric } $\text{N}_2\text{O}_4(\text{Hg}'\text{O}_2)''\text{Hgo}''$.
dinitrate

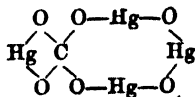
Tetrahydric mercuric } $\text{N}_2\text{O}_4\text{HoHgo}''$.
dinitrate

Tetrahydric dimeric } $\text{N}_2\text{OHoHgo}''$.
dinitrate

Dihydric trimeric } $\text{N}_2\text{OHoHgo}''$.
dinitrate

Trimeric carbonate... $\text{CHgo}''(\text{Hg}'\text{O}_2)''$. 

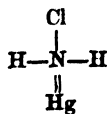
Tetrameric carbonate. $\text{CHgo}''(\text{Hg}'\text{O}_2)''$.



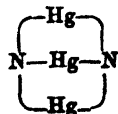
Mercuriosodiammonic } NH_2ClHg }
dichloride } NH_2ClHg }

Mercuriosomercurodi- } $\text{N}_2\text{Hg}''\text{H}_4'\text{Hg}'\text{Cl}_2$.
ammonic dichloride. }

Mercurammonic chlo- } $\text{NH}_2\text{Hg}''\text{Cl}$.
ride. (*White precipitate.*)



Trimeric diamide ... $\text{N}_2\text{Hg}''$.

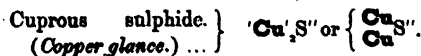
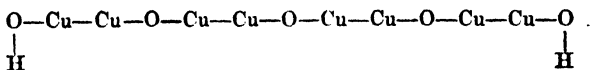
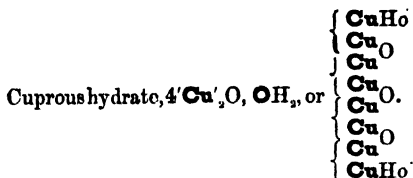
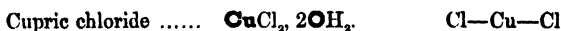
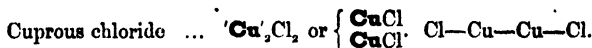
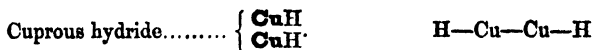


COPPER, Cu.

Atomic weight = 63.5. Probable molecular weight = 63.5. Sp. gr.

8.8. Fuses at about 780°. Atomicity'', also a pseudo-monad.

The following are the names and probable constitutional formulæ of the principal compounds of this metal :—



Cupric sulphide. (*Indigo copper* or *blue copper*.) } CuS'' .

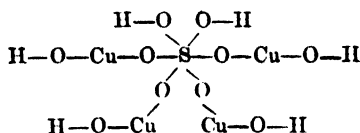
Cupric sulpho-hydrate.. $5\text{CuS}''$, CuHo_2 .

Cupric nitrate..... $\text{NO}_2\text{CuO}''$, 4OH_2 , or $\text{NHo}_4\text{CuO}''$.
 $\text{NO}_2\text{CuO}''$, $\text{NHo}_4\text{CuO}''$.

Dihydric cupricsulphate $\text{SHo}_2\text{CuO}''$, 4OH_2 .

Hydric tricupric sulphate trihydrate... } $\text{SHo}(\text{OCu}''\text{Ho})_3$.

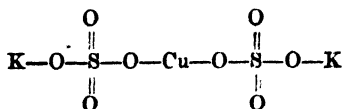
Dihydric tetracupric sulphate tetrahydrate. (*Brochantite*.) } $\text{SHo}_2(\text{OCu}''\text{Ho})_4$.



Hydric pentacupric sulphate pentahydrate } $\text{SHo}(\text{OCu}''\text{Ho})_5$, 2OH_2 .

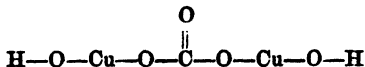
Ammoniocupric sulphate. (*Dihydric diammonic cuprodiammonic sulphate*.) } SHo_2Amo_2 , $[\text{N}^+\text{H}_3\text{CuO}''_2]''$

Dipotassic cupric disulphate { SO_3Ko
 CuO'' .
 SO_3Ko

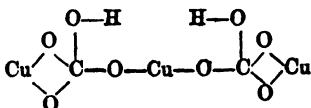


Dicupric carbonate. } CCuO''_2 .
 (*Mysorin*.)

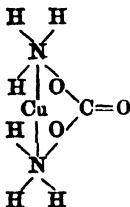
Dicupric carbonatedi- } $\text{CO}(\text{OCu}''\text{Ho})_2$.
hydrate. (*Malachite*.) }



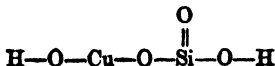
Dihydric tricupric dicar- }
bonate. (*Blue malachite*,
azurite, mountain-blue,
or copper-azure.) } { $\begin{matrix} \text{CHoCu}'' \\ \text{Cu}'' \\ \text{CHoCu}'' \end{matrix}$



Cuprodiammonic carbo- }
nate. (*Ammoniocupric*
carbonate.) } $\text{CO} \left[\begin{smallmatrix} \text{N}^+\text{H}_2 \\ \text{N}^+\text{H}_2 \end{smallmatrix} \text{Cu}''\text{O}_2 \right]''$.



Hydric cupric silicate } $\text{SiOHo}(\text{OCu}''\text{Ho})$.
hydrate. (*Diopase*.) }



CHAPTER XX.

TRIAD ELEMENTS.

SECTION II.

GOLD, Au.

Atomic weight = 196·7. *Probable molecular weight* = 393·4. *Sp. gr.* 19·3 to 19·5. *Fuses at about* 1100°–1200°. *Atomicity' and '''.*

The following are the names and probable constitutional formulæ of the chief compounds of gold :—

Aurous chloride **AuCl.** **Au—Cl.**

Auric chloride **AuCl₂.**

$$\begin{array}{c} \text{Cl} \\ | \\ \text{Au} \\ / \quad \backslash \\ \text{Cl} \quad \text{Cl} \end{array}$$

Aurous iodide **AuI.**

Auric iodide **AuI₂.**

Aurous oxide **Au₂O.** **Au—O—Au**

Auric oxide. (*Auric anhydride.*) $\left\{ \begin{array}{l} \text{AuO} \\ \text{O} \\ \text{AuO} \end{array} \right.$ **O=Au—O—Au=O**

Potassic aurate **AuOKo, 3OH₂.** **O=Au—O—K**

Aurous sulphide..... **Au₂S''.**

Auric sulphide $\left\{ \begin{array}{l} \text{AuS''} \\ \text{S''} \\ \text{AuS''} \end{array} \right.$

SECTION III.

THALLIUM, Tl_2 .

Atomic weight = 204. *Probable molecular weight* = 408. *Sp.*
gr. 11.81 to 11.91. *Fuses at* 294° . *Atomicity* ' and ''.

Evidence of atomicity :—

Thallous chloride	$TlCl$.
Thallous oxide	OTl_2 .
Thallic chloride	$Tl'''Cl_3$.

Occurrence.—In small quantities in certain varieties of pyrites and sulphur, and in minute quantities in some mineral springs.

Preparation.—By extracting with water the deposit formed in the flues of sulphuric acid-chambers, and precipitating the thallous chloride by hydrochloric acid. The chloride is converted into sulphate by the action of sulphuric acid; and when purified, a solution of the sulphate is decomposed by metallic zinc, which precipitates the metallic thallium.

The following list contains the principal compounds of this metal :—

Thallous chloride	$TlCl$.
Thallous oxide	OTl_2 .
Thallic chloride	$TlCl_3$.
Thallic oxide	$\left\{ \begin{array}{l} TlO \\ O \\ TlO \end{array} \right.$
Thallous sulphide	STl_2 .
Thallous nitrate	NO_2TlO .
Thallous sulphate	SO_2TlO_2 .
Thallous carbonate	CO_2TlO_2 .
Thallic oxyhydrate	$TlOHo$.

CHAPTER XXI.

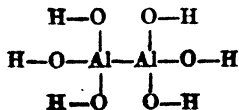
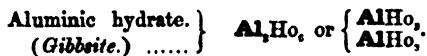
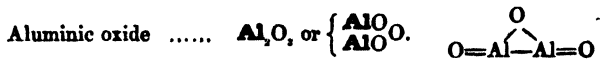
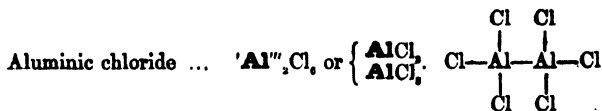
TETRAD ELEMENTS.

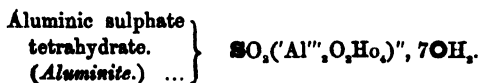
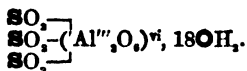
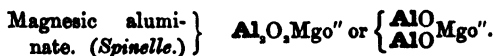
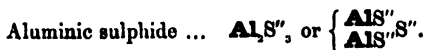
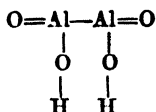
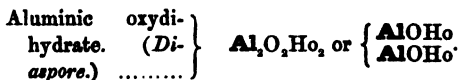
SECTION II.

ALUMINIUM, Al.

Atomic weight = 27.5. Molecular weight unknown. Specific gravity 2.6. Fuses at about 450°. Atomicity 1^v, but is always a pseudo-triad. Evidence of Atomicity—analogy with iron and chromium.

Annexed are the names and probable constitutional formulæ of the most important compounds of this metal :—





Alunite, alum- stone	$\begin{array}{l} \text{SOHoKo} ('Al''', Ho_2O_3)''' \\ \text{SOHo}_2 ('Al''', Ho_2O_3)''' \\ \text{SOHo}_2 ('Al''', Ho_2O_3)''' \\ \text{SOHoKo} ('Al''', Ho_2O_3)''' \end{array}$
Collyrite	$SiHo_2 ('Al''', Ho_2O_3)_n, 4OH_1.$
Dipotassic alumi- nic tetrasul- phate. (<i>Common</i> <i>alum.</i>)	$\begin{array}{l} SO_2Ko \\ SO_2 \\ SO_2 \\ SO_2Ko \end{array} \left\{ ('Al''', O_3)_n, 24OH_1. \right.$
Wörthite.....	$\begin{array}{l} Si \\ SiO ('Al''', Ho_2O_3)_n \\ Si ('Al''', Ho_2O_3)_n \end{array}$
Miloschine	$SiHo_2 ('Al''', Ho_2O_3)_n.$
Porcelain clay of Passau.....	$\begin{array}{l} SiHo_2 ('Al''', Ho_2O_3)_n \\ SiHo_2 ('Al''', Ho_2O_3)_n \end{array}$
Cimolite, kaolin of Ellenbogen	$\begin{array}{l} SiHo_2 \\ SiO \\ SiO \\ SiHo_2 \end{array} \left\{ ('Al''', O_3)_n. \right.$
Agalmatolite	$\begin{array}{l} SiOHo \\ SiO \\ SiO \\ SiOHo \end{array} \left\{ ('Al''', O_3)_n. \right.$
Buchholzite, xeno- lite	$\begin{array}{l} Si \\ Si ('Al''', O_3)_n \\ Si ('Al''', O_3)_n \end{array}$
Porcelain clay..	$\begin{array}{l} SiHo \\ O \\ SiHo \end{array} \left\{ ('Al''', Ho_2O_3)_n. \right.$
Andalusite, chias- tolite, cyanite, fibrolite, sillima- nite	$SiO ('Al''', O_3)_n.$
Wernerite	$Si_2Cao'' ('Al''', O_3)_n.$

Saponite	$\text{Si}_2\text{Mgo}''', \text{Ho}_{10}(\text{'Al'''}', \text{O}_6)''$.
Lepidolite	$\text{Si}_2\text{O}_2\text{Ko}, \text{Lio}_2(\text{'Al'''}', \text{O}_2)''_2(\text{'Al'''}', \text{F}_2\text{O}_2)''$.
Analcime	$\left\{ \begin{array}{l} \text{SiHo}_2\text{Nao} \\ \text{O} \\ \text{Si}(\text{'Al'''}', \text{O}_2)'' \\ \text{O} \\ \text{SiHo}_2\text{Nao} \end{array} \right.$
Razoumoffskin	$\left. \begin{array}{l} \text{SiHo}_2 \\ \text{SiHo}_2 \\ \text{SiHo}_2 \end{array} \right\} (\text{'Al'''}', \text{O}_2)''$
Malthacite	$\text{Si}_2\text{O}_{11}\text{Ho}_2(\text{'Al'''}', \text{O}_2)''$.
Albite	$\left\{ \begin{array}{l} \text{SiONao} \\ \text{SiO} \\ \text{O} \\ \text{SiO} \\ \text{SiO} \\ \text{O} \\ \text{SiO} \\ \text{SiONao} \end{array} \right\} (\text{'Al'''}', \text{O}_2)''$

CHAPTER XXII.

TETRAD ELEMENTS.

SECTION III.

. PLATINUM, Pt.

Atomic weight = 197.4. Molecular weight unknown. Sp. gr.
21.5. Atomicity '' and iv.

The following compounds will serve to illustrate the atomicity and general character of this metal :—

Platinous chloride ... PtCl_2 . $\text{Cl}-\text{Pt}-\text{Cl}$

Platinic chloride..... PtCl_4 . $\begin{array}{c} \text{Cl} \\ | \\ \text{Cl}-\text{Pt}-\text{Cl} \\ | \\ \text{Cl} \end{array}$

Platinous oxide PtO .

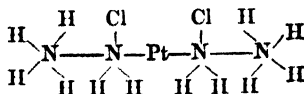
Platinic oxide PtO_2 . $\text{O}=\text{Pt}=\text{O}$

Platinous hydrate ... PtH_2O_2 .

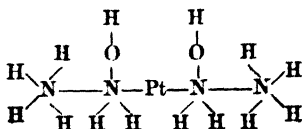
Platinic hydrate..... PtH_4O_4 .

Platinosodiammonic dichloride. $\left\{ \begin{array}{l} \text{NH}_4\text{Cl} \\ \text{Pt}'' \\ \text{NH}_4\text{Cl} \end{array} \right.$ $\begin{array}{c} \text{Cl} \quad \quad \text{Cl} \\ | \quad \quad | \\ \text{H}-\text{N}-\text{Pt}-\text{N}-\text{H} \\ | \quad \quad | \\ \text{H} \quad \quad \text{H} \end{array}$
(Green salt of Magnus.)

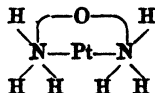
White compound of $\left\{ \begin{array}{l} \text{NH}_4(\text{N}\cdot\text{H}_4)\text{Cl} \\ \text{Pt}'' \\ \text{NH}_4(\text{N}\cdot\text{H}_4)\text{Cl} \end{array} \right.$
 Reiset



Platoso-diammon di- $\left\{ \begin{array}{l} \text{NH}_4(\text{N}\cdot\text{H}_4)\text{Ho} \\ \text{Pt}'' \\ \text{NH}_4(\text{N}\cdot\text{H}_4)\text{Ho} \end{array} \right.$
 ammonic dihydrate



Platosodiammonic ox-
ide $\left\{ \begin{array}{c} \text{NH}_3 \\ \text{Pt}'' \\ \text{NH}_3 \end{array} \right\} \text{O}.$



Platinous sulphide ... $\text{PtS}''.$

Platinic sulphide ... $\text{PtS}''_2.$

CHAPTER XXIII.

TETRAD ELEMENTS.

SECTION IV.

LEAD, Pb.

Atomic weight = 207. Molecular weight unknown. Sp. gr. 11.445. Fuses at 327°. Boils at a white heat. Atomicity " and iv. Also sometimes a pseudo-triad.

The following list contains the names and probable constitutional formulæ of the most interesting compounds of this metal:—

Plumbic chloride ... $\text{PbCl}_2.$



Plumbous oxide $\left\{ \begin{array}{c} \text{Pb} \\ \text{O} \\ \text{Pb} \end{array} \right\}$

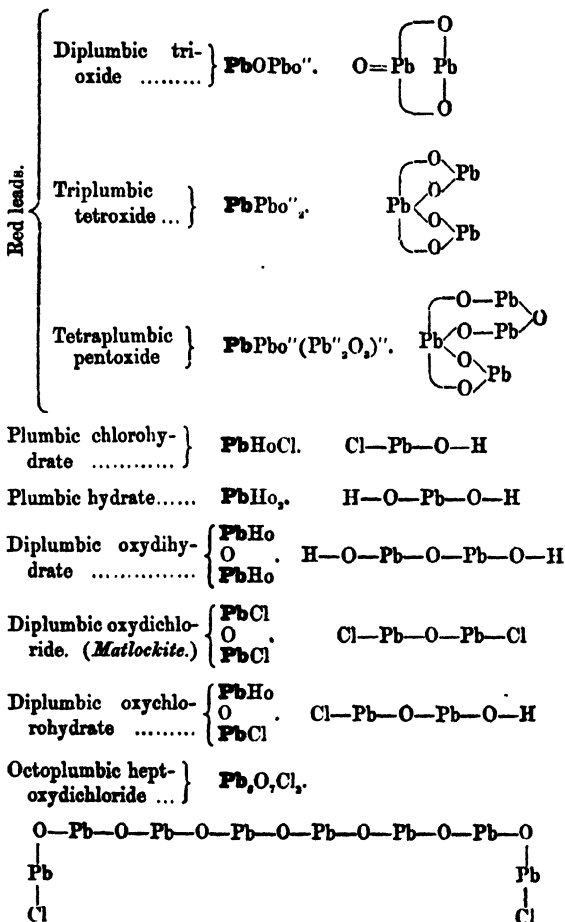


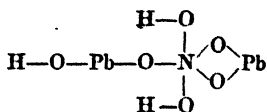
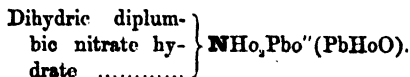
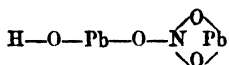
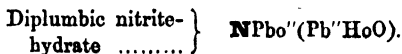
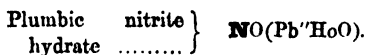
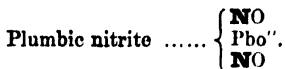
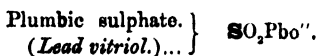
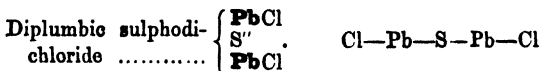
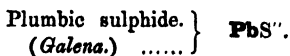
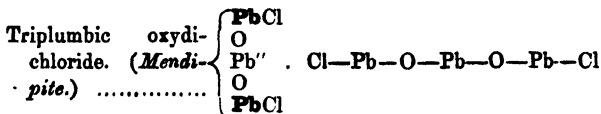
Plumbic oxide. } $\text{PbO}.$
(Litharge.) }

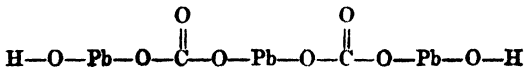
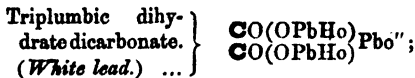
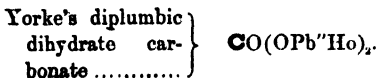
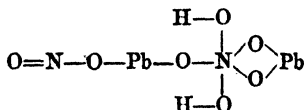
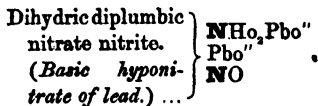


Plumbic peroxide. } $\text{PbO}_2.$
(Plattnerite.) ... }

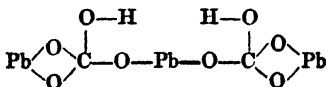
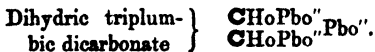


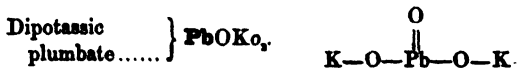
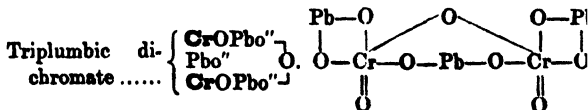
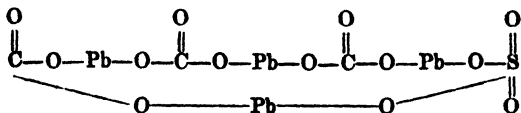
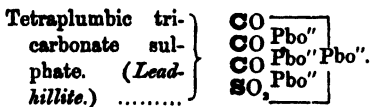
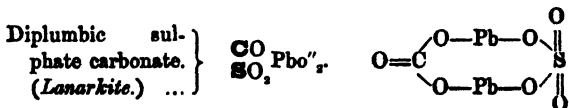






or





CHAPTER XXIV.

HEXAD ELEMENTS.

SECTION IV.

CHROMIUM, Cr.

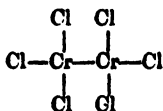
Atomic weight = 52.5. *Molecular weight unknown. Sp. gr.* 7.0146. *Atomicity* ", iv, and vi; also a *pseudo-triad* (and a *pseud-octad*). *Evidence of atomicity*:—See the annexed compounds.

The following are the names and probable constitutional formulæ of the most important compounds of this metal:—

Chromous chloride CrCl_2 .



Chromic chloride ... $\left\{ \begin{array}{l} \text{CrCl}_2 \\ \text{CrCl}_2 \end{array} \right.$



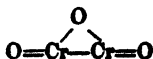
Chromic perfluoride CrF_6 .

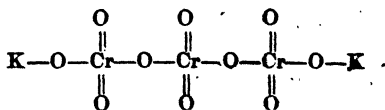
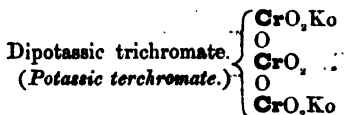
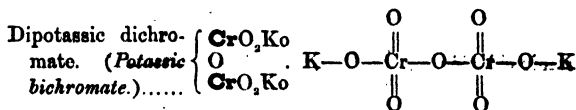
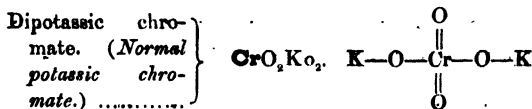
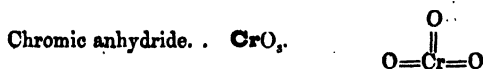
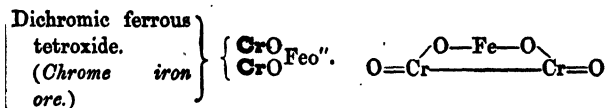
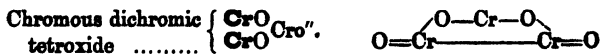


Chromous oxide CrO .

Chromous hydrate ... CrHO_2 .

Chromic oxide $\left\{ \begin{array}{l} \text{CrO} \\ \text{CrO} \end{array} \right. \text{O}.$





Dipotassic chromous } $\text{SO}_2\text{KoCr}^{\text{II}}, 6\text{OH}_2.$
disulphate } SO_2Ko

Chromic sulphate ... { SO_2 —
 SO_2 —($\text{Cr}^{\text{III}}, \text{O}_6$)^{vi}, $15\text{OH}_2.$
 SO_2 —

Dipotassic chromic } SO_2Ko
sulphate (*Potas-*) } SO_2 —($\text{Cr}^{\text{III}}, \text{O}_6$)^{vi}, $24\text{OH}_2.$
sium chrome alum.) } SO_2Ko

Chromic nitrate $\text{N}_6\text{O}_{12}(\text{Cr}^{\text{III}}, \text{O}_6)^{\text{vi}}.$

Octochromic carbo- } $\text{C}(\text{Cr}^{\text{III}}, \text{O}_{13}\text{H}_6)^{\text{iv}}.$
nate dihydrate ... }

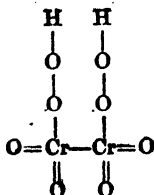
Plumbic chromate. } $\text{CrO}_2\text{Pbo}^{\text{II}}.$
(*Red lead ore,* }
crocoisite.) }

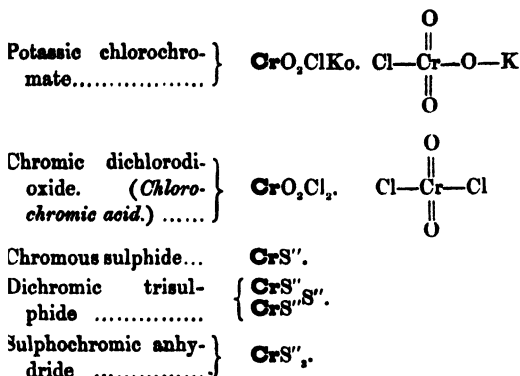
Sulphochromic acid. { SO_2Ho
(*Dihydric sulphate* } O
chromate.) { CrO_2Ho

Tetrapotassic dichro- { CrOKo—O_2 } $\text{S}^{\text{VI}}\text{Ko}_2.$
mosulphate { O
 CrOKo—O_2

Chromic hydrate { $\text{CrHo}_3, 6\text{OH}_2.$
 CrHo_3

Perchromic acid { $\text{CrO}_2(\text{OHo}).$
 $\text{CrO}_2(\text{OHo}).$



**MANGANESE, Mn.**

Atomic weight = 55. Molecular weight unknown. Sp. gr. 7 to 8. Atomicity " , iv, and vi; also a pseudo-triad and a pseud-octad. Evidence of atomicity:—

Manganic perfluoride $\text{Mn}^{\text{vi}}\text{F}_6.$

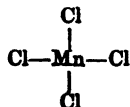
Analogy with chromium.

The following are some of the more important compounds of this element:—

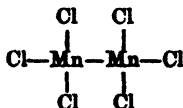
Manganous chloride. $\text{MnCl}_2.$



Manganic chloride ... $\text{MnCl}_3.$



Dimanganic hexachloride { $\text{MnCl}_3.$
 $\text{MnCl}_3.$



Manganous hydrate.. MnHo_2 . $\text{H}-\text{O}-\text{Mn}-\text{O}-\text{H}$

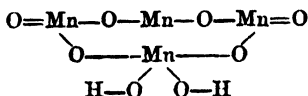
Manganous oxide ... MnO . $\text{Mn}=\text{O}$

Manganous dimanganic tetroxide. $\left\{ \begin{array}{l} \text{MnO} \\ \text{MnO} \end{array} \right\} \text{Mno}''$. $\begin{array}{c} \text{O}-\text{Mn}-\text{O} \\ \text{O}=\text{Mn}-\text{Mn}=\text{O} \end{array}$
(*Hausmannite*.) ...

Dimanganic trioxide. $\left\{ \begin{array}{l} \text{MnO} \\ \text{MnO} \end{array} \right\} \text{Mno}''$. $\begin{array}{c} \text{O} \\ \text{O}=\text{Mn} \quad \text{Mn} \\ \text{O} \end{array}$
(*Braunite*.)

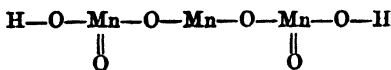
Dimanganic dioxydihydrate. (*Manganite*.) $\left\{ \begin{array}{l} \text{MnHo}_2 \\ \text{MnO} \end{array} \right\} \text{Mno}''$. $\begin{array}{c} \text{H}-\text{O} \quad \text{O} \\ \text{H}-\text{O} \quad \text{Mn} \quad \text{O} \quad \text{Mn} \\ \quad \quad \text{O} \end{array}$

Varvicite..... $\left\{ \begin{array}{l} \text{MnO} \\ \text{Mno}'' \\ \text{MnO} \end{array} \right\} (\text{Mn}^{\text{iv}}\text{O}_2\text{Ho}_2)''$



Manganic oxide. $\left\{ \begin{array}{l} \text{MnO}_2 \end{array} \right\}$
(*Pyrolusite*.)

Manganous dimanganic tetroxide dihydrate. (*Psilomelane*, *Hartmannite*.) $\left\{ \begin{array}{l} \text{MnOHo} \\ \text{MnOHo} \end{array} \right\} \text{Mno}''$.



Dipotassic manganate MnO_3Ko_2 . $\begin{array}{c} \text{O} \\ \parallel \\ \text{K}-\text{O}-\text{Mn}-\text{O}-\text{K} \\ \parallel \\ \text{O} \end{array}$

Dipotassic per- manganate	$\left\{ \begin{array}{l} \text{MnO}_3(\text{OKo}) \\ \text{MnO}_3(\text{OKo}) \end{array} \right.$	$ \begin{array}{c} \text{K} \quad \text{K} \\ \quad \\ \text{O} \quad \text{O} \\ \quad \\ \text{O} \quad \text{O} \\ \quad \\ \text{O}=\text{Mn}-\text{Mn}=\text{O} \\ \quad \\ \text{O} \quad \text{O} \end{array} $
Manganous sul- phide. (<i>Man- ganece blende.</i>)...	$\left\{ \begin{array}{l} \text{MnS.} \end{array} \right.$	
Disulphopotassic trimanganous disulphide	$\left\{ \begin{array}{l} \text{MnKs} \\ \text{MnKs} \end{array} \right. \text{Mns}''$	
Manganous carbo- nate. (<i>Manga- nese spar.</i>)	$\left\{ \begin{array}{l} \text{COMno}'' \end{array} \right.$	
Dihydric manga- nous sulphate ...	$\left\{ \begin{array}{l} \text{SOHo, Mno}'', (3, 4, \text{ or } 6\text{OH}_2) \end{array} \right.$	
Dipotassic manga- nous disulphate. }	$\left\{ \begin{array}{l} \text{SO}_2\text{Ko} \\ \text{SO}_2\text{Ko} \end{array} \right. \text{Mno}'', 6\text{OH}_2$	
Aluminic manga- nous tetrasul- phate. (<i>Manga- nese aluminium alum.</i>)	$\left\{ \begin{array}{l} \text{SO}_2 \\ \text{SO}_2 \\ \text{Mno}''' \\ \text{SO}_2 \\ \text{SO}_2 \end{array} \right\} \text{Al}''', \text{O}_6)^{\text{vi}}, 24\text{OH}_2$	
Dimanganic trisul- phate	$\left\{ \begin{array}{l} \text{SO}_2 \\ \text{SO}_2 \\ \text{SO}_2 \end{array} \right\} (\text{Mn}''', \text{O}_6)^{\text{vi}}$	
Dipotassic diman- ganic tetrasul- phate. (<i>Potas- sium manganese alum.</i>)	$\left\{ \begin{array}{l} \text{SO}_2\text{Ko} \\ \text{SO}_2 \\ \text{SO}_2 \\ \text{SO}_2\text{Ko} \end{array} \right\} (\text{Mn}''', \text{O}_6)^{\text{vi}}, 24\text{OH}_2$	

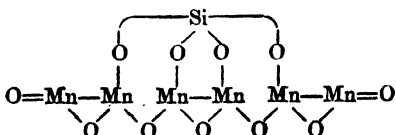
Manganous hydric phosphate $\text{POHoMno}''$.

Manganous silicate. (*Siliciferos manganese, red manganese, rother Mangankiesel, Rothbraunsteinerz.*) SiOMno'' .

Dimanganous silicate. (*Tephroite.*) SiMno''_2 .

Dihydric dimanganous silicate dihydrate. (*Schwarzer Mangankiesel.*) $\text{SiH}_2(\text{OMuHo})_2$.

Hexamanganic monosilicate. (*Heterocline.*) $\text{Si}(\text{Mn}''''_6\text{O}_{11})^{iv}$.



Trigluccinic tetramanganous trisilicate sulphide. (*Helvine.*) $\left\{ \begin{array}{l} \text{SiGlo}'' \\ \text{Mno}'' \\ \text{SiGlo}'' \\ \text{Mno}'' \\ \text{SiGlo}'' \end{array} \right\} \left(\begin{array}{c} \text{Mn}''\text{O}'' \\ \text{S}'' \\ \text{Mn}''\text{O}'' \end{array} \right)$.

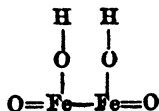
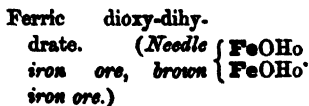
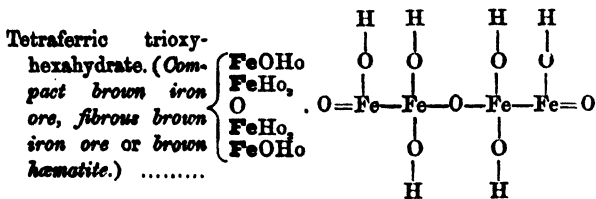
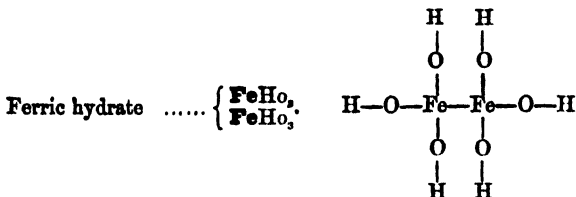
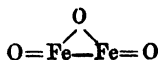
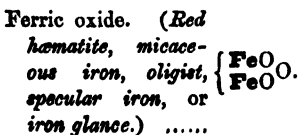
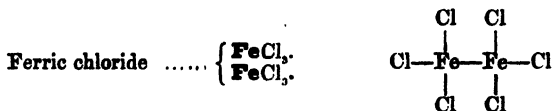
Aluminic manganous disilicate. $\left\{ \begin{array}{l} \text{Si} \\ \text{Mno}'' \\ \text{Si} \end{array} \right\} (\text{Al}'''\text{O}_3)^{vi}, 2\text{OH}_2$.

IRON, Fe.

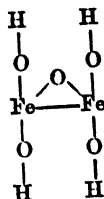
Atomic weight = 56. *Molecular weight* unknown. *Sp. gr.* 7·8. *Atomicity* ", iv, and vi. *Evidence of atomicity—analogy with chromium.*

The following is a list of the chief compounds of iron :—

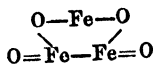
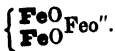
Ferrous chloride ... FeCl_2 $\text{Cl}-\text{Fe}-\text{Cl}$
o 2



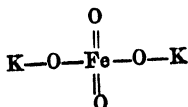
Ferric oxy-tetra-
hydrate. (Another
variety of *brown*
iron ore.)



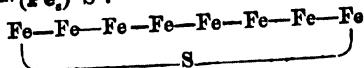
Ferrous ferric te-
troxide. (*Magnetic*
iron ore.)



Potassic ferrate FeO_2K_2 .



Octoferrous sulphide $\text{xiv} (\text{Fe}_8)''\text{S}''.$



Diferrous sulphide... $\left\{ \begin{array}{l} \text{FeS}'' \\ \text{FeS}'' \end{array} \right.$

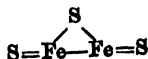


Ferrous sulphide ... $\text{FeS}''.$

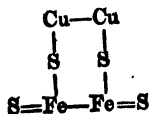
Ferric disulphide. $\left\{ \begin{array}{l} \text{FeS}'' \\ \text{FeS}'' \end{array} \right.$
(*Iron pyrites,*
martial pyrites.)



Diferric trisulphide $\left\{ \begin{array}{l} \text{FeS}''\text{S}'' \\ \text{FeS}''\text{S}'' \end{array} \right.$



Diferric cuprous te-
trasulphide. (*Cop- per pyrites.*) $\left\{ \begin{array}{l} \text{FeS} \\ \text{FeS} \end{array} \right. (\text{Cu}_2\text{S}'')''.$



Ferric nitrate $\text{N}_2\text{O}_{12}(\text{Fe}'''_2\text{O}_6)^{\text{vi}}$.

Hexahydric di-
ferric diphos-
phate dihydrate. } $\text{P}_2\text{H}_6(\text{Fe}'''_2\text{H}_6\text{O}_6)^{\text{vi}}$.

Ferrous sulphate ... $\text{SOH}_6\text{Feo}''', 6\text{OH}_2$.

Dipotassic ferrous di-
sulphate { SO_2Ko
 Feo''' , 6OH_2 .
 SO_2Ko

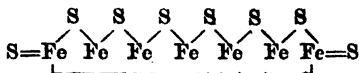
Ferric sulphate. } SO_2
(*Coquimbite*.) ... { SO_2 — $(\text{Fe}'''_2\text{O}_6)^{\text{vi}}$, 9OH_2 .
 SO_2 —

Dipotassic ferric
tetrasulphate. } SO_2Ko
(*Potassium iron*
alum.) { SO_2 — $(\text{Fe}'''_2\text{O}_6)^{\text{vi}}$, 24OH_2 .
 SO_2 — SO_2Ko

Tetraferric sulphate.. $\text{SO}_4(\text{Fe}'''_4\text{O}_6)''$, 6OH_2 .

Tetrahydric tetra-
ferric sulphate
octahydrate. } $\text{SH}_6(\text{Fe}'''_4\text{OH}_6\text{O}_6)''$.
(*Vitriol ochre*.) }

Heptaferric octo-
sulphide. (*Mag-
netic pyrites*.) ... } Fe_7S_{11} .



Ferrous carbonate. }
(*Spathic iron*
ore.) { COFeo'' .

Ferrous nitrate ... { NO_2
 Feo'' .
 NO_2

COBALT, Co.

Atomic weight = 58.8. *Molecular weight unknown.* *Sp. gr.* 8.5.

Atomicity ", iv, and vi? also a pseudo-triad.

For evidence of the atomicity of cobalt see the following list of the chief compounds of this metal:—

Cobaltous chloride ...	CoCl_2	$\text{Cl}-\text{Co}-\text{Cl}$
Cobaltic chloride ...	$\left\{ \begin{array}{l} \text{CoCl}_2 \\ \text{CoCl}_3 \end{array} \right.$	$\begin{array}{c} \text{Cl} \quad \text{Cl} \\ \quad \\ \text{Cl}-\text{Co}-\text{Co}-\text{Cl} \\ \quad \\ \text{Cl} \quad \text{Cl} \end{array}$
Cobaltous oxide	CoO	$\text{Co}=\text{O}$
Cobaltic oxide.....	$\left\{ \begin{array}{l} \text{CoO} \\ \text{CoO} \end{array} \right. \text{O}$	$\begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{O}=\text{Co}-\text{Co}=\text{O} \end{array}$
Cobaltous dicobaltic tetroxide	$\left\{ \begin{array}{l} \text{CoO} \\ \text{CoO} \end{array} \right. \text{CoO}''$	$\begin{array}{c} \text{O}-\text{Co}-\text{O} \\ \diagup \quad \quad \quad \diagdown \\ \text{O}=\text{Co} \quad \quad \quad \text{Co}=\text{O} \end{array}$
Hexacobaltic hept- oxide	$\left\{ \begin{array}{l} \text{Co}_7\text{O}_{17} \end{array} \right.$	$\begin{array}{c} \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \\ \diagup \quad \diagdown \quad \diagup \quad \diagdown \quad \diagup \quad \diagdown \\ \text{O}=\text{Co}-\text{Co}-\text{Co}-\text{Co}-\text{Co}-\text{Co}=\text{O} \end{array}$
Cobaltous hydrate	CoHo_2	$\text{H}-\text{O}-\text{Co}-\text{O}-\text{H}$
Cobaltic oxy-dihydrate	$\left\{ \begin{array}{l} \text{CoOHo} \\ \text{CoOHo} \end{array} \right.$	$\begin{array}{c} \text{H}-\text{O} \quad \text{O}-\text{H} \\ \quad \\ \text{O}=\text{Co}-\text{Co}=\text{O} \end{array}$
Cobaltous sulphide.....	CoS''	
Cobaltic sulphide. (<i>Cobalt pyrites.</i>)	$\left\{ \begin{array}{l} \text{CoS}'' \\ \text{CoS}'' \end{array} \right. \text{S}''$	

NICKEL, Ni.

Atomic weight = 58·8. *Molecular weight unknown.* *Sp. gr.* 8·7.

Atomicity ", iv, and vi ? also a pseudo-triad.

Annexed is a list of the names and probable constitutional formulæ of the chief compounds of this metal :—

Nickelous chloride NiCl_2 . $\text{Cl}-\text{Ni}-\text{Cl}$

Nickelous oxide NiO .

Nickelic oxide..... $\left\{ \begin{array}{l} \text{NiO} \\ \text{NiO} \end{array} \right.$ $\begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{O}=\text{Ni}-\text{Ni}=\text{O} \end{array}$

Nickelic hydrate..... $\left\{ \begin{array}{l} \text{NiHo}_2 \\ \text{NiHo}_2 \end{array} \right.$ $\begin{array}{c} \text{H}-\text{O} \quad \text{O}-\text{H} \\ | \quad | \\ \text{H}-\text{O}-\text{Ni}-\text{Ni}-\text{O}-\text{H} \\ | \quad | \\ \text{H}-\text{O} \quad \text{O}-\text{H} \end{array}$

Nickelous hydrate NiHo_2 .

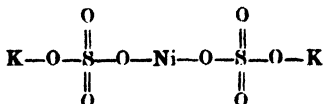
Dinickelous sulphide ... $\left\{ \begin{array}{l} \text{Ni} \\ \text{Ni} \end{array} \right. \text{S}''$.

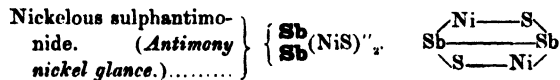
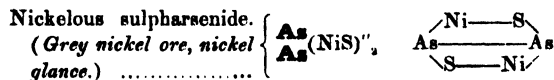
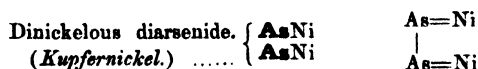
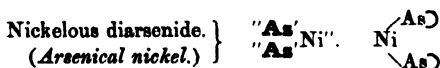
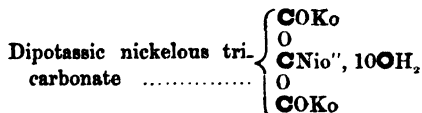
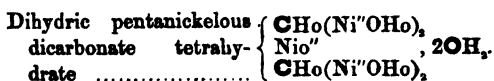
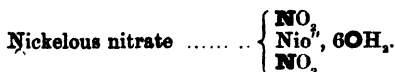
Nickelous sulphide. $\left. \begin{array}{l} \text{(Capillary pyrites,} \\ \text{hair nickel.)} \end{array} \right\} \text{NiS}''$.

Nickelic disulphide..... NiS_2 . $\text{S}=\text{Ni}=\text{S}$

Dihydric nickelous $\left. \begin{array}{l} \text{sulphate} \end{array} \right\} \text{SOHo, Nio'', 6OH}_2$.

Dipotassic nickelous di- $\left\{ \begin{array}{l} \text{SO}_3\text{Ko} \\ \text{Nio'', 6OH}_2 \\ \text{SO}_3\text{Ko} \end{array} \right.$
sulphate





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